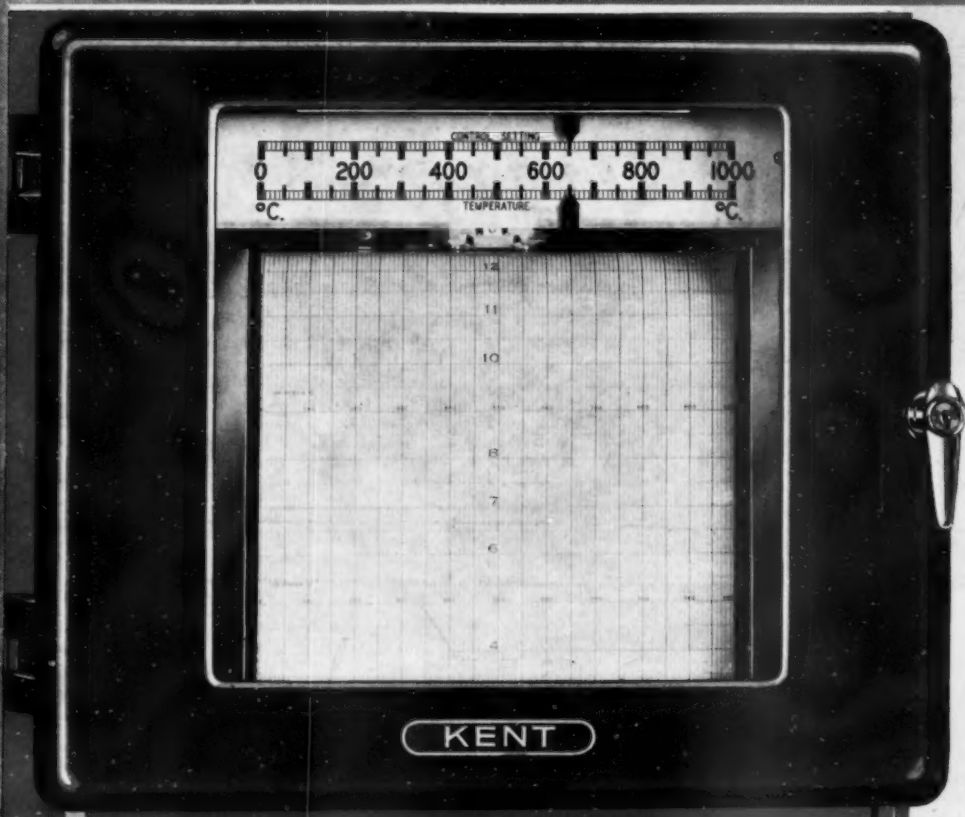
Vol. 19. No. 114. APRIL, 1939 Price 2/- [Subscription 24/- per annum, post free.]

METALLURGIA

THE BRITISH JOURNAL OF METALS

669.05
M 562



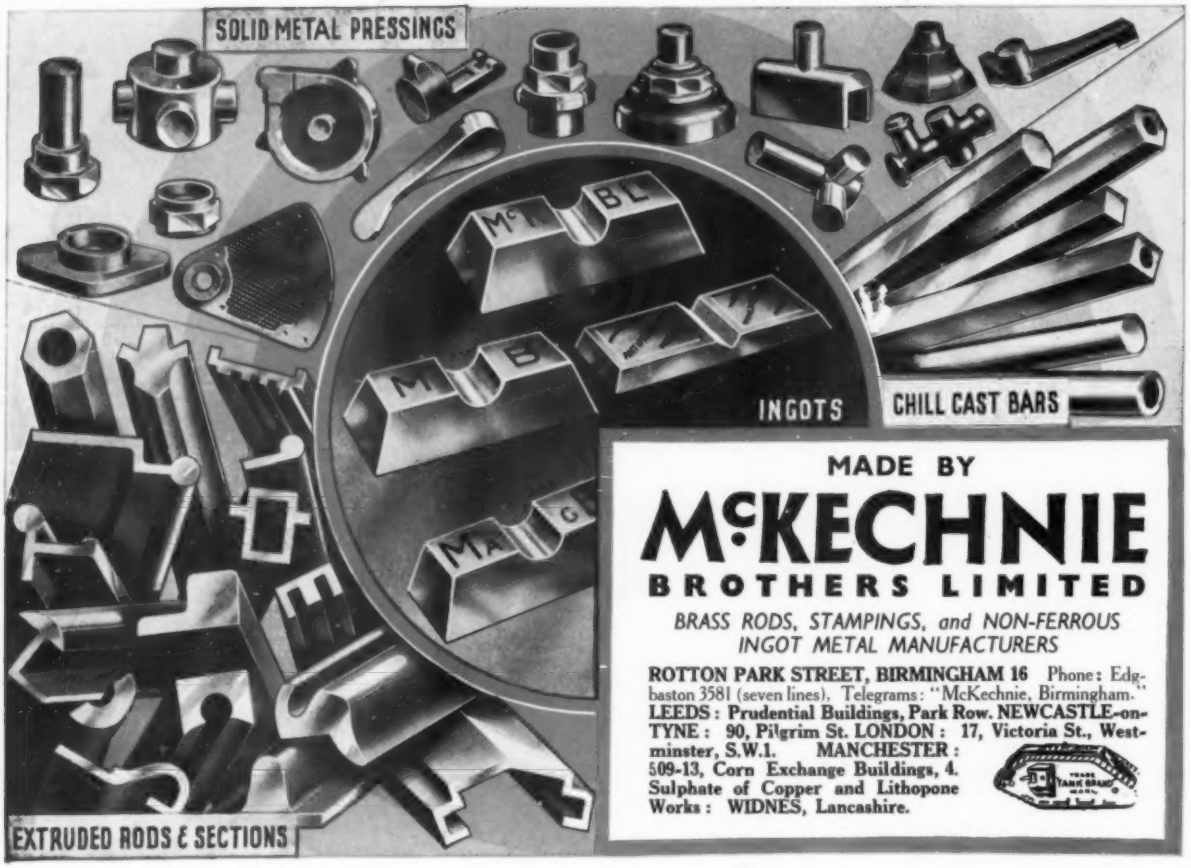
THE MARK II MULTELEC
FOR
TEMPERATURE
RECORDING
AND CONTROL

GEORGE KENT LTD., LUTON, BEDFORDSHIRE
London Office: 200 High Holborn, W.C.1

This instrument retains the outstanding advantages of the Mark I Multelec, but has been modified to incorporate the following special features :—

1. *10 in. length of chart visible, with large bold scale.*
2. *Chart can be cut off and will continue to drive. A plate is provided on the front of the instrument to facilitate making notes on the chart.*
3. *A multi-colour record can be provided, if desired.*
4. *The indicator on the scale is specially arranged so as to be visible at long distances.*
5. *The multi-point recorders have a target indicator which shows from some distance which point the recorder is measuring.*
6. *Chart speeds are provided, 1 in., 2 in. and 3 in., change effected by moving a lever.*
7. *Exceptional ease of fitting chart.*
8. *Manual standardising is easily carried out from the front.*
9. *All mechanism is enclosed in covers within the front case, wherever possible, including transparent dust and draught-proof cover for the galvanometer.*
10. *On and off and floating control available.*

GEORGE KENT



MADE BY

McKECHNIE BROTHERS LIMITED

BRASS RODS, STAMPINGS, and NON-FERROUS INGOT METAL MANUFACTURERS

ROTTON PARK STREET, BIRMINGHAM 16 Phone: Edgbaston 3581 (seven lines). Telegrams: "McKechnie, Birmingham." **LEEDS: Prudential Buildings, Park Row. NEWCASTLE-on-TYNE: 90, Pilgrim St. LONDON: 17, Victoria St., Westminster, S.W.1. MANCHESTER: 509-13, Corn Exchange Buildings, 4. Sulphate of Copper and Lithopone Works: WIDNES, Lancashire.**

VITREOSIL IMMERSION HEATERS

PLATING AND PICKLING

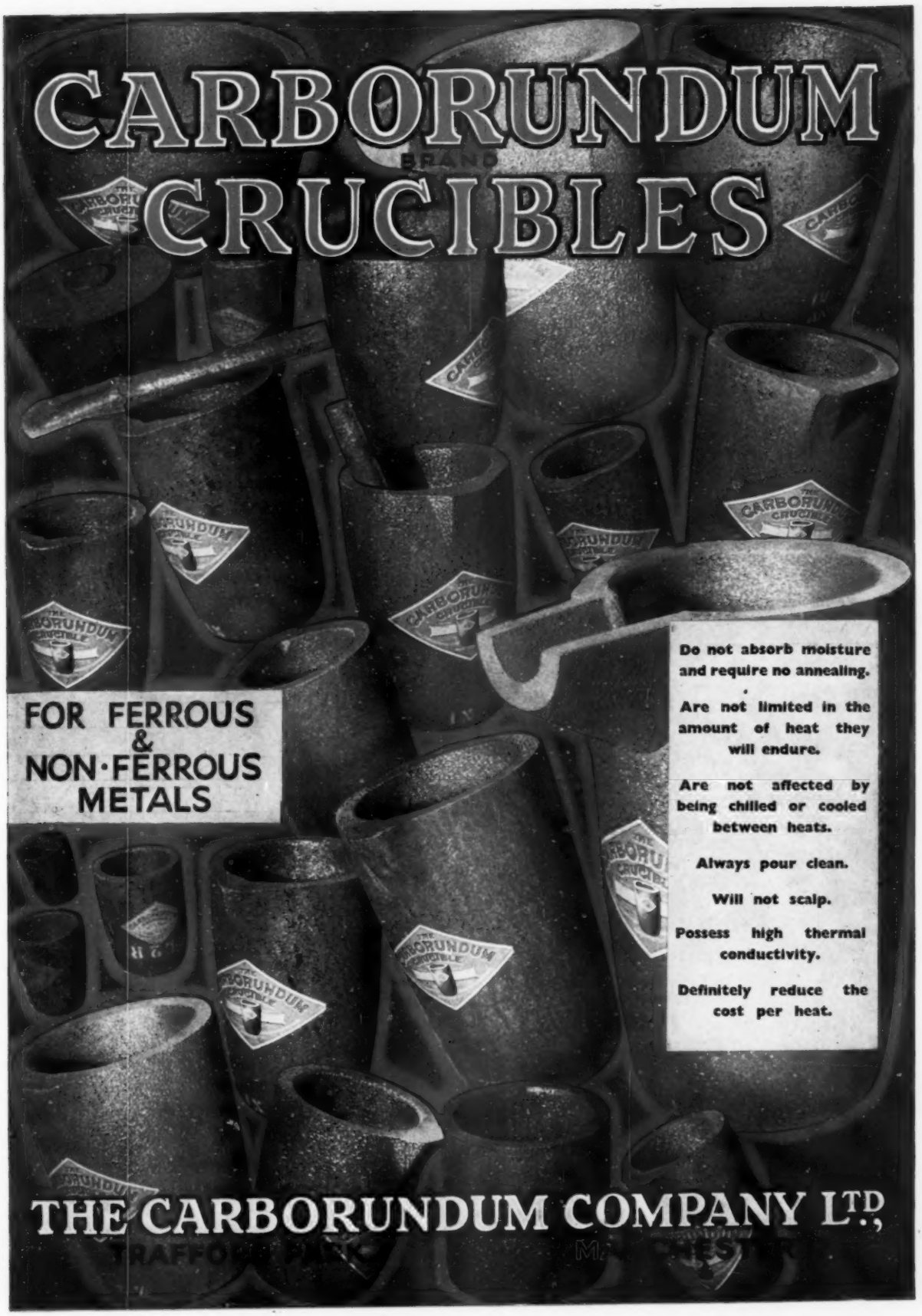
Baths for these operations can be effectively heated and maintained at constant temperature by VITREOSIL electric immersion heaters. The envelope is acid and heat proof so there is no contamination of the bath. The material also permits a high element temperature, therefore small construction. These heaters are in use in a large English wire works.

A price list of standard heaters is now available.

THE THERMAL SYNDICATE LTD.

Head Office and Works: **Wallsend, Northumberland**
London Depot: **12-14, Old Pye St., Westminster, S.W.1.**

ESTABLISHED OVER 30 YEARS.


CARBORUNDUM
BRAND
CRUCIBLES
FOR FERROUS & NON-FERROUS METALS
Do not absorb moisture and require no annealing.
Are not limited in the amount of heat they will endure.
Are not affected by being chilled or cooled between heats.
Always pour clean.
Will not scalp.
Possess high thermal conductivity.
Definitely reduce the cost per heat.
THE CARBORUNDUM COMPANY LTD.,

Electric Steel Furnaces

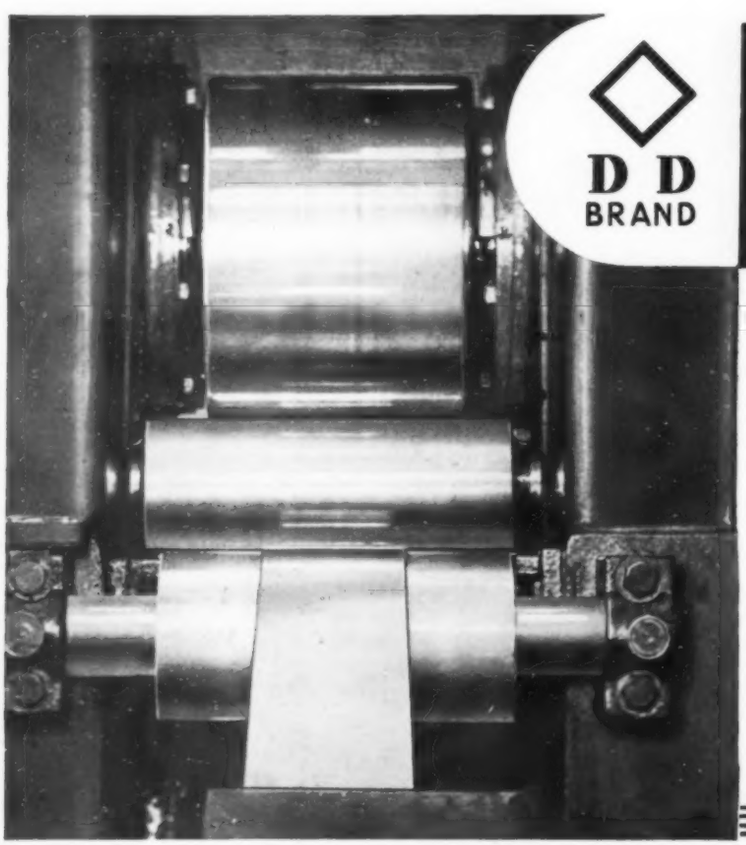
with Basket Charging and Vessel Turning Gear enabling huge savings to be made in the cost of breaking up and charging scrap.

The basket shown in the illustration contains a charge of 35 tons, made up of steel rolls and tops. The charge is not dropped on to the hearth of the furnace, but laid gently down on to it without the slightest bump.

Further particulars may be had on application to address below.

Demag-Elektrostahl GEGR.
DUISBURG

Agent: P. HEUSER, 119, Victoria Street, London S.W. 1. 'Phone Victoria 2612.



D D BRAND

HARDENED STEEL ROLLS

for all
cold-rolling operations

You can specify D-Diamond-D Brand British-Made Hardened Steel Rolls with every confidence. We have been supplying some of the largest cold rollers of steel and non-ferrous metals for years.

EVERY ROLL CERTIFIED

Every Roll is accompanied by a certificate giving particulars of size, hardness tests, etc.

DANIEL DONCASTER & SONS LIMITED
Penistone Road, Sheffield
Telephone: 43081 (5 lines)
Telegrams: Doncasters, Sheffield

1

Prosaic Puppetry

Romance lies not in articles, but in the mind behind the eye which beholds them. To some, a lorry, an aeroplane, a motor car, is but a dead, unliving thing. To others, it represents a product of man's creative genius, symbolical of pioneers who faced the world's unbelief, confident of what would one day be. Had but these pioneers known Hiduminium, their confidence would indeed have reaped earlier reward. Hiduminium lightens the heaviest parts of an engine. No metal that is lighter, is as strong; none that is stronger, is as light. Hiduminium, in itself, is a pioneer; but a pioneer which no man dare doubt, for Hiduminium and the increased performance that it brings have been proved in all parts of the world, in countless varied applications.

HIDUMINIUM R.R. ALLOYS

HIGH DUTY ALLOYS LIMITED · SLOUGH · BUCKS

TYPICAL STAMPING IN HIDUMINIUM R.R.56

UNGERER

is building as sole speciality

Roller Sheet Levellers

which produce results as illustrated in all metals: strips, sheets or plates up to 10 feet wide by ½ inch in thickness.

MOST MODERN CONSTRUCTION.

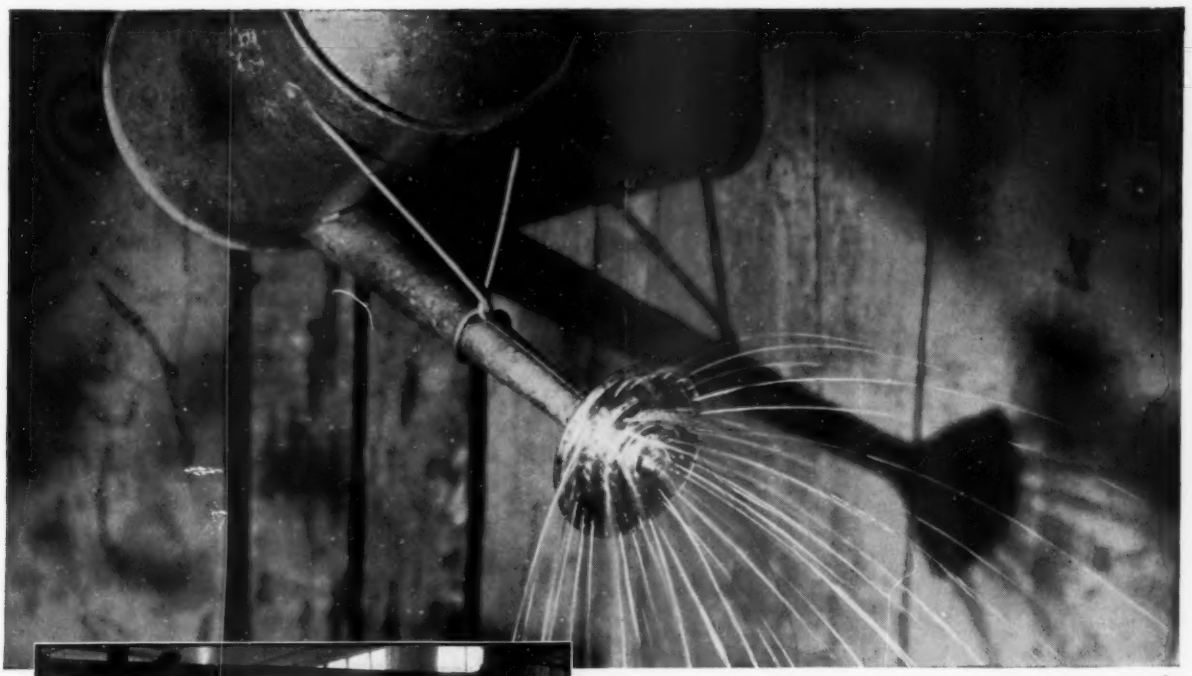
PATENTED IN ALL COUNTRIES.

ESTABL. UNGERER 1895

KARL FR. UNGERER · ENGINEERING WORKS, PFORZHEIM-BRÖTZINGEN, GERMANY

Sole Agents in Great Britain :
INCANDESCENT HEAT CO. LTD.,
SMETHWICK, BIRMINGHAM.

Technical Representative:
EMIL HAAG, 197, HOLLY ROAD,
BIRMINGHAM 20.



BILLET-HEATING FURNACE
at the works of Messrs. Peglers Ltd., Doncaster, fired by PULVERITE.

A good soaking **HEAT**

PULVERITE is the perfect fuel for all types of Billet Heating, Forge, Stamping and Re-heating Furnaces, where a soft soaking heat penetrating evenly to the core of the billet is required.

PULVERITE is the modern industrial fuel for all metallurgical furnaces, being considerably lower in cost than any other fuel giving equal flexibility of control over furnace temperature and atmosphere,

PULVERITE is a perfectly safe and stable fuel. It is produced under strict laboratory control to a guaranteed specification from the finest British coals. Supplies are, therefore, always assured in Peace or War.

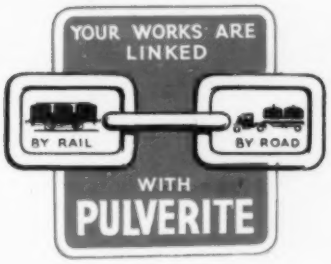
PULVERITE is delivered to your Works by Road or Rail in Tank Wagons, from which it is discharged through a pipe into your bunker with equal cleanliness and convenience to liquid fuels.

Pulverite
THE MODERN INDUSTRIAL FUEL

Manufactured exclusively by
THE STANDARD PULVERISED FUEL CO., LTD.,
Canada House, 4-5, Norfolk Street, LONDON, W.C.2

Telegrams: Gasifuel, Estrand, London
Telephone: Temple Bar 5977

Works and Branch Offices:
GRIMETHORPE WORKS, Nr. Barnsley, Yorks.
BRANCEPETH WORKS, Willington, Co. Durham
DOWELL'S WHARF, Greenwich, London, S.E. 10



SAMUEL FOX ELECTRIC STEELS

"The heart of the engine"

FOX ELECTRIC STEEL

THE UNITED STEEL COMPANIES LTD

- CONSISTENT IN QUALITY
- REGULAR IN BEHAVIOUR
- RIGIDLY INSPECTED

The technical book "Electric Steel Developments" Ref. F.211 is available to aeronautical engineers on application to:—

SAMUEL FOX & CO. LTD., STOCKSBRIDGE, SHEFFIELD

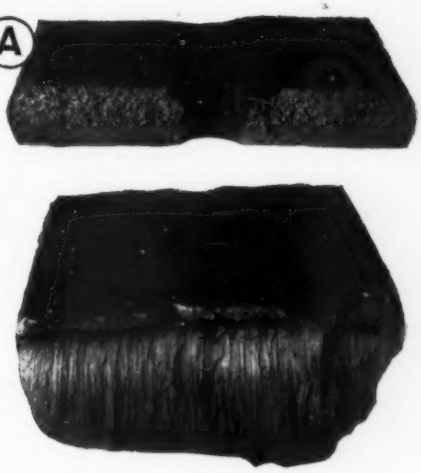
Associated with The United Steel Companies Limited

Telegrams: "Fox" Deepcar

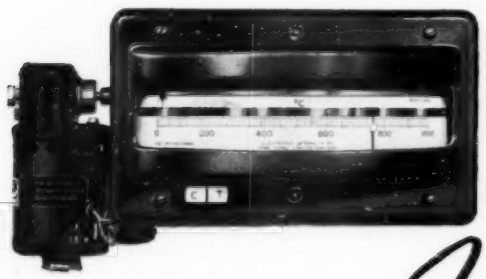
Telephone: Oughtibridge 40871

F.155

THE PROOF IS IN THE TEST PIECE—



Electroflo Automatic Control of gas-fired furnaces saved a Railway Company considerable sums of money by ensuring that rolling stock leaf springs were correctly heat treated. Fractures, as shown in (a), were frequent before the automatic control was adopted and involved the Company in considerable losses in lay-off periods and repair costs. Additionally, the twenty-five Electroflo Automatic Control Pyrometers reduced the furnace gas consumption by 19%, or more than £1,000 per annum. This installation was made in 1933. Electroflo Automatic Temperature Control is sold on the basis of guaranteed results as determined indisputably by your Laboratory's report on your test piece.



Specify

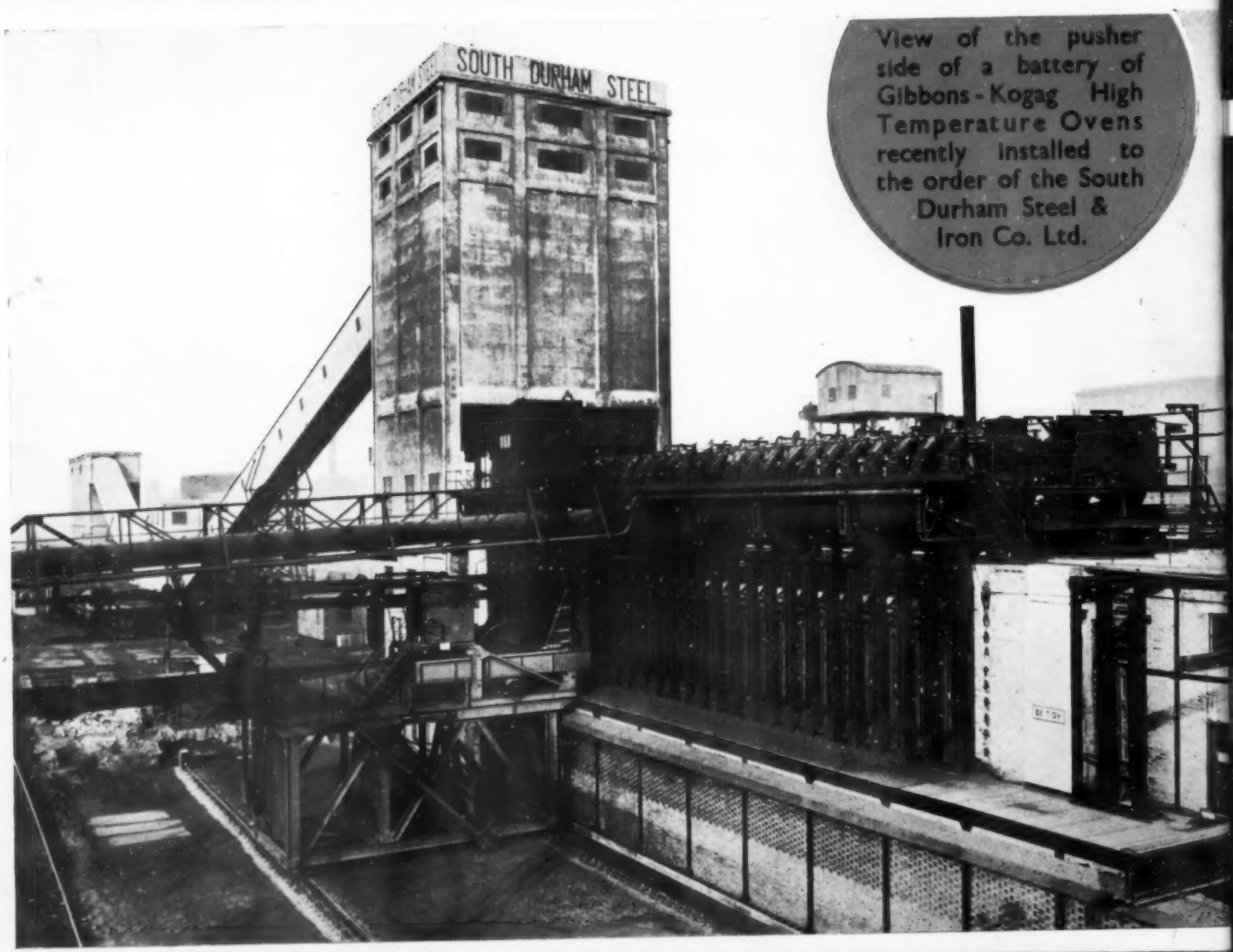
ELECTROFLO

AUTOMATIC TEMPERATURE CONTROL

for guaranteed results with the maximum heat economy

GIBBONS-KOGAG HIGH TEMPERATURE COKE OVENS AND BY-PRODUCT PLANT

GIBBONS



View of the pusher side of a battery of Gibbons-Kogag High Temperature Ovens recently installed to the order of the South Durham Steel & Iron Co. Ltd.

GIBBONS BROS. LIMITED,

KOGAG

OKE OVENS

Detailed view of 30 Gibbons-Kogag High Temperature Coke Ovens at Seaton Carew, showing self-sealing doors cross-over main and governor control, also combined pushing and levelling machine.

DUDLEY, WORCESTER . . .

ROBERTSON

WIRE BAR & TUBE DRAWING EQUIPMENT

Every detail in Robertson draw-benches is the outcome of very many years leadership in this class of equipment. Upon receipt of particulars regarding the material and sizes to be drawn, together with the output required, we shall be pleased to furnish particulars of suitable machines and the power they absorb.

W. H. A. ROBERTSON & Co LTD BEDFORD ENGLAND

Tensile Strength–16 tons per sq. inch. Proof Stress – 5 tons per sq. inch

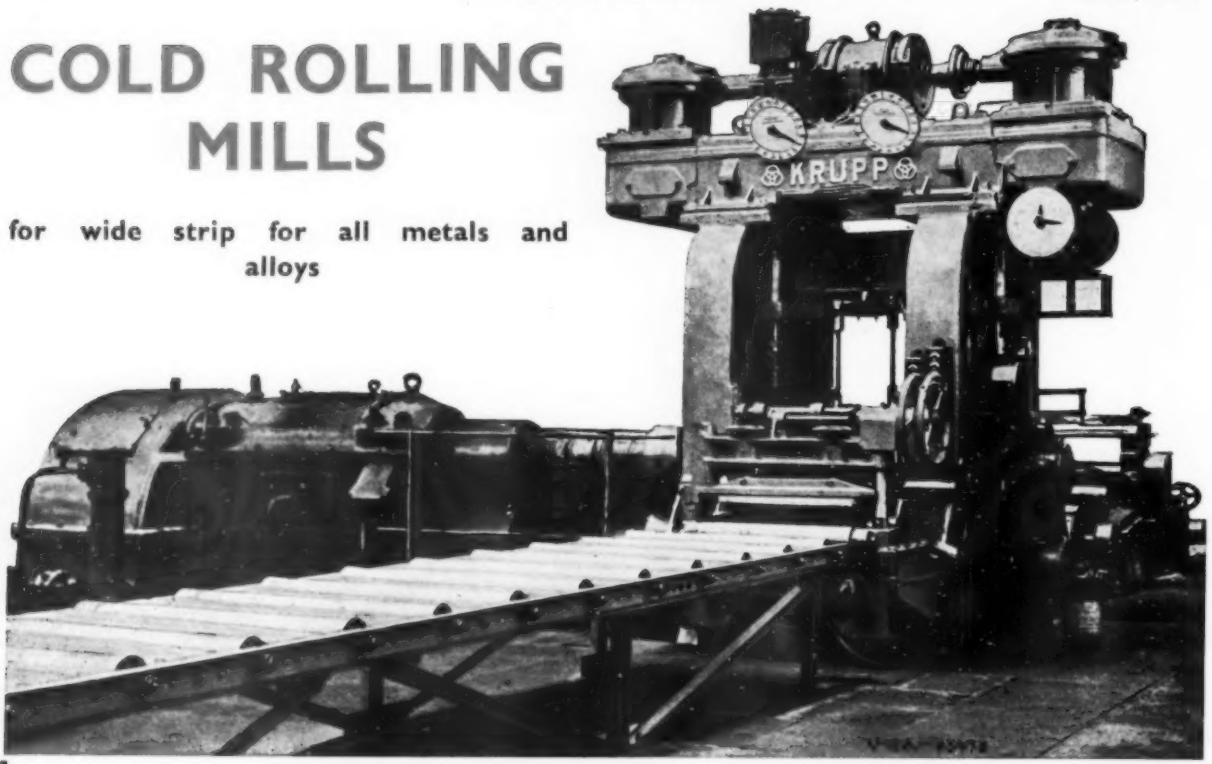
MAGNUMINIUM
CASTINGS

MAGNESIUM CASTINGS & PRODUCTS LTD SLOUGH

TGS

COLD ROLLING MILLS

for wide strip for all metals and alloys



Sole Agents in Gt. Britain :
JOHN ROLLAND
& CO. LTD.
Abbey House, 2 Victoria St.
LONDON, S.W.1.

KRUPP-GRUSONWERK

PRIEST FURNACES

for **Forge, Drop Stamp and Continuous Billet Heating; for Shipyard and Boiler-plate Reheating . . . . . for all Heat-treatment, including Annealing and Normalizing**

We are experts in the design and installation of Melting Furnaces for Steel, Iron and Non-Ferrous Metals.
It will be in your interest to consult us for your requirements for Drying Stoves, and for Industrial Heating of all kinds.

PRIEST FURNACES LTD.,

LONGLANDS :: MIDDLESBROUGH

Phone : Middlesbrough 3871-2 *Grams : " Priest, Middlesbrough."*

"Sea Cliff" Brand

COPPER, BRASS and PHOSPHOR BRONZE

TUBES, SHEETS, RODS and WIRE

"Aldurbra" Aluminium-Brass Condenser Tubes,
Protected under B.N.F. Patent No. 308647—1929.

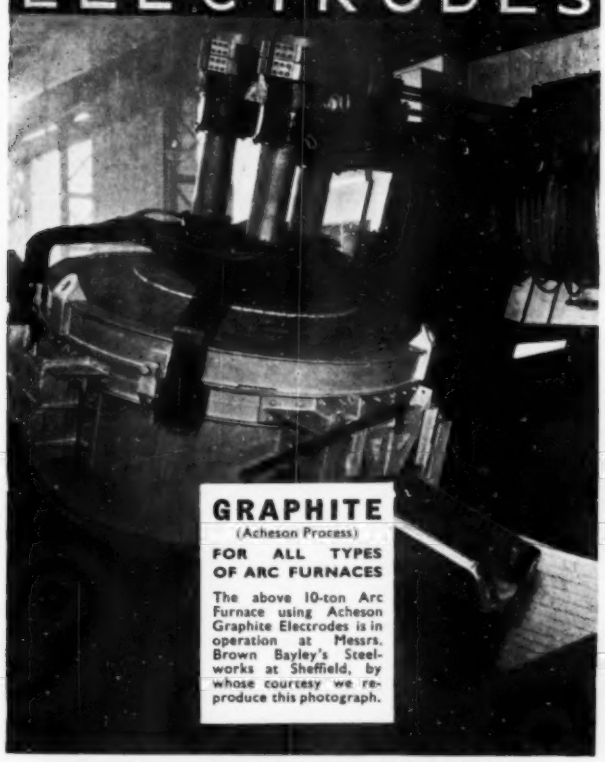
Manganese Bronze. Yellow Metal. Naval Brass. Gun Metal.
High Conductivity Copper Bars and Strip.
Tin, Lead, Zinc and Compo Wire and Strip.
Chill-Cast Phosphor Bronze Bars.
Engraving Bronzes, Gilding Metals, and Engraving Brasses.
Phosphor Copper and Phosphor Tin.
All Wires for Metal Spraying.

SEA CLIFF
Trade Mark.

CHARLES CLIFFORD & SON LTD.
Telegrams: Clifford Birmingham.
Telephone: Mid. 2152, Pte.-Bch.Ex. BIRMINGHAM
ESTABLISHED 1767.

Contractors to Admiralty, War Office, Air Board, Railway Companies, etc.

ELECTRODES



GRAPHITE
(Acheson Process)
FOR ALL TYPES OF ARC FURNACES

The above 10-ton Arc Furnace using Acheson Graphite Electrodes is in operation at Messrs. Brown Bayley's Steelworks at Sheffield, by whose courtesy we reproduce this photograph.

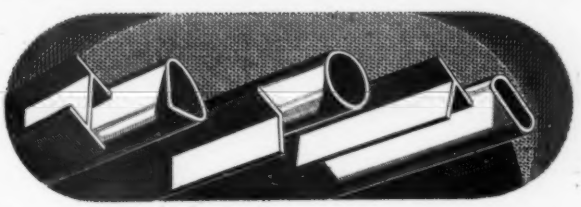
BRITISH ACHESON ELECTRODES Ltd.
GRANGE MILL LANE, WINCOBANK, SHEFFIELD

AND WHAT IS YOUR HANDICAP?

Superfluous avoirdupois is always a handicap on mobility—whether in sport or Industry. In sport—it may cause the loss of a game. In Industry it means day-in, day-out wastage of power—it is a continuous "brake" on earning capacity. For all "things that move" in modern Industry today, "heavy weight" metals must inevitably give way to—

REYNOLDS

TUBES, RODS, SECTIONS, SHEET & STRIP IN HIGH STRENGTH ALUMINIUM & MAGNESIUM ALLOYS



REYNOLDS TUBE CO. LTD. REYNOLDS ROLLING MILLS LTD.
TYSELEY, BIRMINGHAM.

CASTINGS *in* ALUMINIUM

WILIAM MILLS·LTD.
GROVE STREET.
BIRMINGHAM.

SCHMITZ- STRIP ROLLING MILLS FOR ALL KIND OF METAL

TWO- AND FOUR-HIGH, CLUSTER AND HIGH-SPEED ROLLING MILLS
with forged and hardened steel rolls, for cold rolling iron, steel, brass, copper, aluminium, etc.

GRAFA

WALZMASCHINENFABRIK·AUGUST SCHMITZ DÜSSELDORF GERMANY

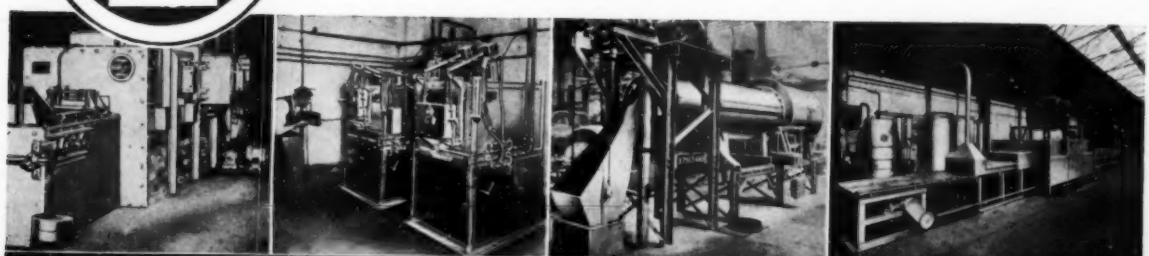
Have you ever realised

. . . ***what*** the pioneering investigations of BIRLEC in the Bright Annealing of Metals have meant to manufacturers of Sheet, Strip, Wire, Tube, Pressings, etc. . . . the elimination of pickling costs and delays . . . reduced metal losses . . . improved life of dies . . . lower handling charges . . . savings in polishing and other finishing processes . . . and the great advantage of preserving and even *improving* the pristine surface of the metal ?

Just one of the many chapters in metallurgical history where BIRLEC specialist engineers have pioneered, and advanced heat treatment practice to new conceptions of economy and quality.

BIRLEC

PIONEERS IN BRIGHT ANNEALING



THERE IS A TYPE OF BIRLEC FURNACE FOR EVERY HEAT TREATMENT PURPOSE

BIRMINGHAM ELECTRIC FURNACES LTD., ERDINGTON, BIRMINGHAM 24

DEMAG

Steelworks Plants

We design and build complete Steelworks Plants, i.e., Open-hearth, Basic Bessemer or Electric Steelworks, with all accessory equipments, auxiliary machines, cranes, and transporting plants.

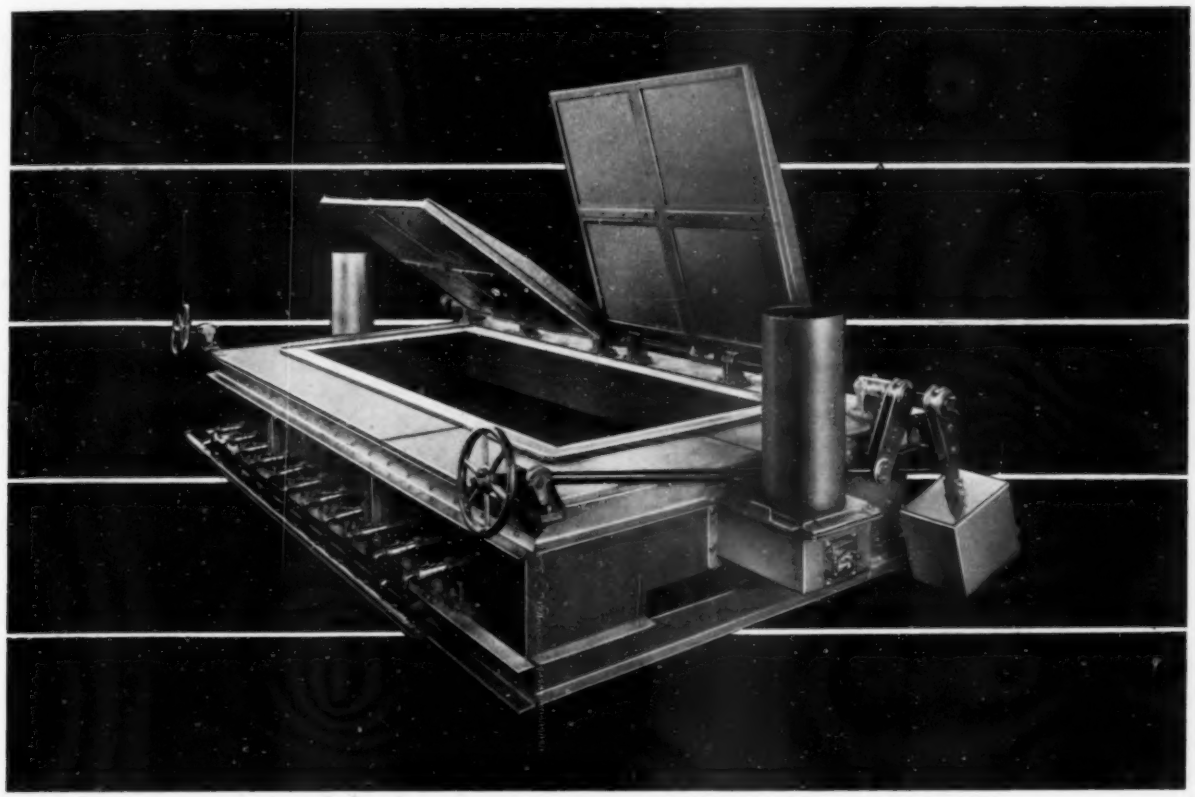
For further information please apply to the following addresses :

For Steelworks Equipment, Rolling Mills, Cranes, Loading Bridges, Excavators and Surface Mining Equipment :
P. HEUSER, 119, Victoria Street, LONDON, S.W.1 Tel. Victoria 2612/3

For Pulley Blocks and Suspension Cranes :
AABACAS ENGINEERING CO., LTD. Grange Road, BIRKENHEAD. Tel. 4747.

For Compressors of all kinds and Pneumatic Tools :
THE ROTARY AIR COMPRESSOR CO., LTD., 119, Victoria Street, LONDON, S.W.1 Tel. Victoria 2612.

For Underground Mining Equipment :
H. E. MASSMANN, Broadway Chambers, 7, Broadway Ludgate Hill, LONDON, E.C.4. Tel. City 4869.



SALT BATH TREATMENT

In the accurate heat treatment of aluminium, duralumin and other light alloys, furnace design is of major importance. High thermal efficiency; temperature control; maximum furnace life and simplicity of operation are the features which form the basis of design for Incandescent Salt Baths. The above illustration showing a rectangular town gas fired salt bath with a bath 11 ft. x 4 ft. 6 in. x 1 ft. deep is typical of many Incandescent installations in use throughout the aircraft and allied industries.

INCANDESCENT Heat Co LTD

CORNWALL ROAD · SMETHWICK · BIRMINGHAM ·

GAS PLANTS & FURNACES

PRODUCER GAS FIRED BAR AND ANGLE FURNACE

Specialists in the manufacture of

CLEAN GAS PRODUCER PLANTS using coke, anthracite or bituminous fuel

●

FURNACES OF ANY TYPE fired by gas, oil or solid fuel

●

OVER 50 YEARS EXPERIENCE

● *If you have a heating problem consult the*

DOWSON & MASON GAS PLANT COMPANY LTD.

ALMA WORKS LEVENSHULME MANCHESTER

LIKE GEORGE WASHINGTON

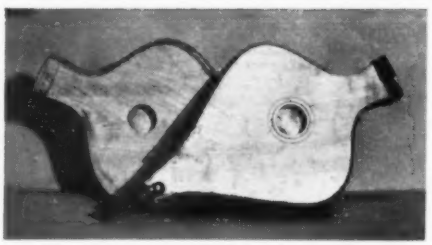
—it cannot tell a lie

This Ether Checking and Portable Pyrometer was designed to tell the truth, the whole truth, and nothing but the truth. Accuracy is built into it. Fitted with high resistance spring mounted movement, auto cold junction compensation and every refinement to give accuracy and robustness. Used extensively for checking instruments essential for exacting Air Ministry work.

ETHER

LIMITED · TYBURN RD · BIRMINGHAM

FOUNDRY SUPPLIES



May we quote you for your Foundry Furnishings ? — prompt delivery guaranteed for urgent orders.

BLACKINGS ◦ COAL DUST

Send your enquiries for Blackings and Coal Dusts. For a specially fine finish we recommend Carlton Patent Blacking—one of the finest obtainable. Coal Dusts are prepared from the best grades of Durham Coal, and are carefully screened and bagged.

SAMPLES. We will be glad to let you have samples of any of our products so that you may compare values. There is naturally no obligation.

THOMAS **WILKINSON** & CO. LTD.

STOCKTON STREET · MIDDLESBROUGH

Telephone: 3719 'Grams "Blacking" Middlesbrough

BRITAIN'S MOST MODERN AIRLINER IS BUILT WITH NORAL 'ALCLAD' SHEET

MECHANICAL PROPERTIES OF 'ALCLAD' NA 23S TO DTD 390	
.1% Proof stress tons sq. inch	15
Ultimate Tensile Strength tons sq. inch	25
Elongation % on 2"	15

★ The elongation figures refer to sheet and strip thicker than 12 SWG.

'Alclad' was chosen for the de Havilland Flamingo because of its proved superior workability and low maintenance costs; two important considerations in a commercial plane which has to maintain a rigid schedule in all weathers.

These machines, now in production, will be built of 'Alclad' 23S sheet, a new alloy recently perfected to combine the best properties of a number of alloys and so simplify the sheet-metal worker's choice of material.

This sheet consists of a core of NA 23S with a coating of high purity aluminium on each surface, which not only protects the alloy where covering is complete, but also electrolytically protects the base metal when exposed at sheared edges or by deep scratches and abrasions. It also affords substantial electrolytic protection to rivets of the base metal.

As the largest suppliers of aluminium sheet for aircraft production, we are able to offer sheet metal workers valuable assistance in their problems. Please consult our Advisory Service Department.

M. 15

NORTHERN ALUMINIUM Co. Ltd.

BUSH HOUSE, ALDWYCH, LONDON, W.C.2 · Telephone: TEMPLE BAR 8844 · Telegrams: NORALUCO, BUSH, LONDON
and at BANBURY, BIRMINGHAM, BRISTOL, COVENTRY, GLASGOW, MANCHESTER, NEWCASTLE-ON-TYNE & SHEFFIELD

TRUE TO TYPE

Wide chest, broad straight back, muscular thighs, short sturdy legs — every quality necessary for heavy draught work has been standardised in the Shire Horse. Similarly, exact and unvarying standards of manufacture, backed by an unrivalled research service, ensure consistent high quality in the products of I.C.I. Metals Ltd. These non-ferrous alloys have long established a reputation for *uniform* excellence; each is notable for its reliability, each is true to type.

Manufactured by I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6. Enquiries should be addressed to: Imperial Chemical Industries Ltd., Dept. M12, Imperial Chemical House, Millbank, S.W.1

Sales Offices at: Belfast, Birmingham, Bradford, Bristol, Dublin, Glasgow, Hull, Liverpool, London, Manchester, Newcastle-on-Tyne, Shrewsbury, Swansea.

Mr. John Gould's Shire Mare LYMM LADY GREY
Female Champion at the Royal Show, Cardiff, 1938
Photograph by courtesy of THE FARMER & STOCKBREEDER

FOR CONSISTENT HIGH QUALITY—SPECIFY

I.C.I. METALS

INDUSTRIAL ART
SERVICES LTD
21, ALBION ST.
GAYTHORN
MANCHESTER.

PICTURES have an international appeal knowing no bounds of language.

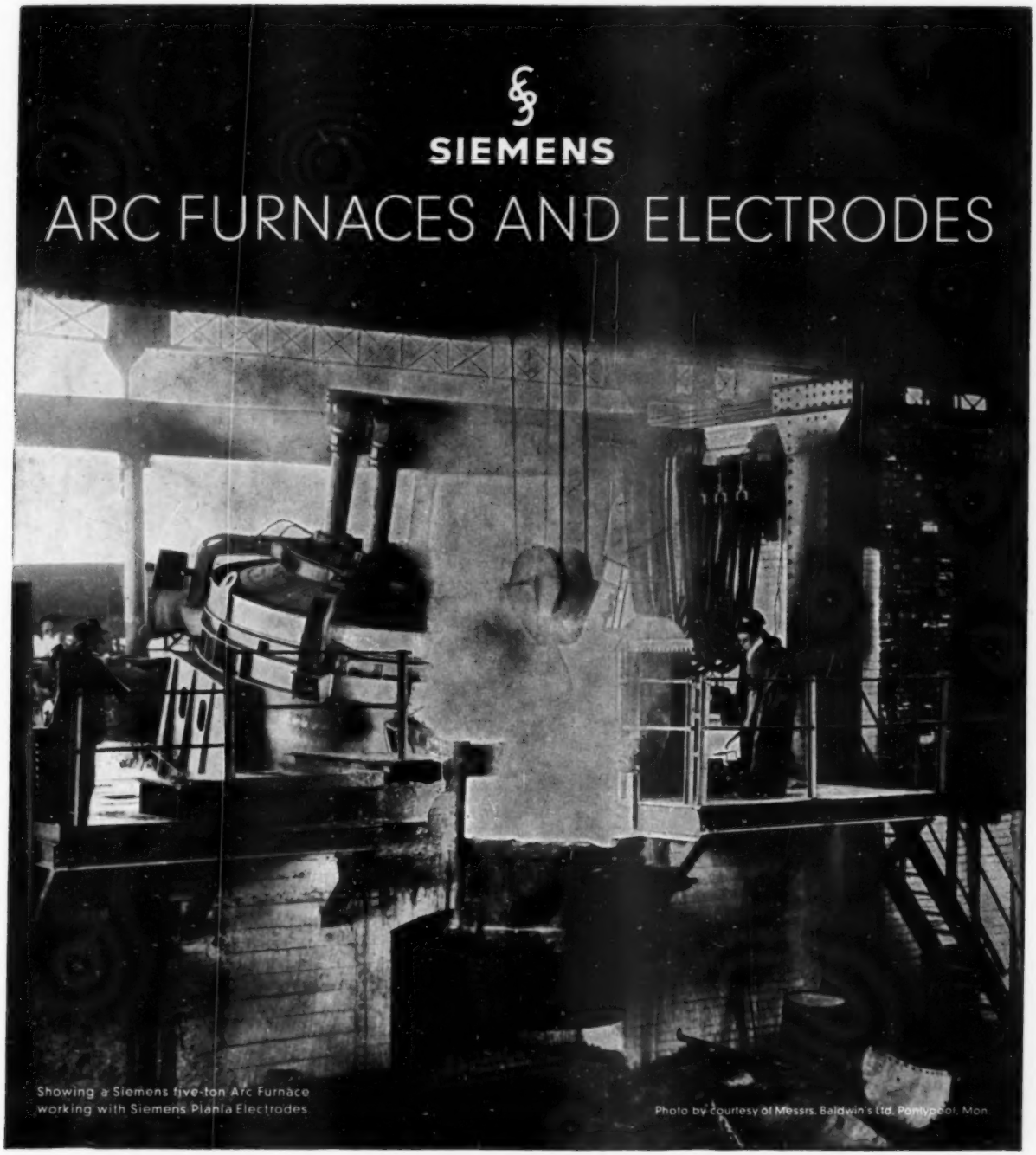
They tell their story quickly and convincingly —If they are good pictures.

We have specialised in engineering subjects for many years and our artists appreciate the engineers' outlook. They can put life and action into otherwise dull and uninteresting photographs in a manner that pleases the eye without offending the engineers' sense of correctness.

For your next photographs and drawings of machines, plant etc., consult, without obligation,

INDUSTRIAL ART SERVICES LTD

Telephone CEN 2574

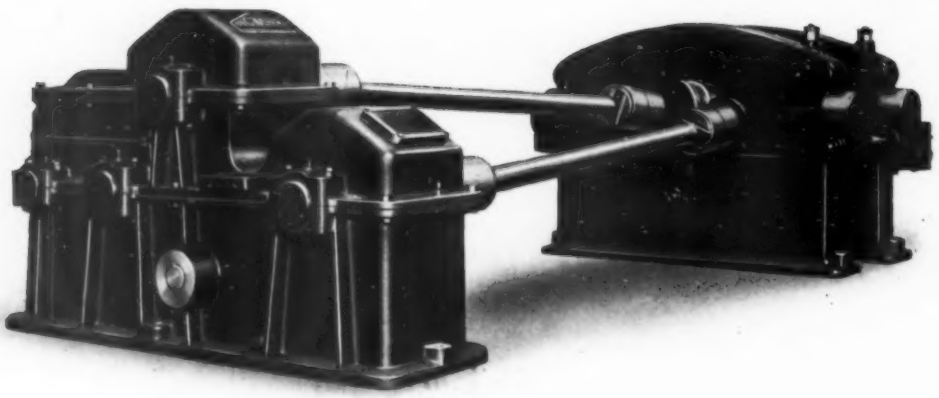

SIEMENS
ARC FURNACES AND ELECTRODES
Showing a Siemens five-ton Arc Furnace working with Siemens Plania Electrodes
Photo by courtesy of Messrs. Baldwin's Ltd. Pontypool, Mon

More than 200

Siemens Melting and Reduction Furnaces are working satisfactorily and economically with SIEMENS PLANIA ELECTRODES. We are in a position to supply suitable Electrodes for any Electro-Metallurgical and Electro-Chemical Process.

SIEMENS-SCHUCKERT (GREAT BRITAIN) LTD · GREAT WEST ROAD · BRENTFORD · MIDDLESEX

REELING MACHINES



● The above illustration shows a Machine for Reeling tubes up to 5½" in diameter. We make a complete range of these machines for Cold and Hot Reeling and Straightening.

WE SPECIALISE IN ALL TYPES OF STRAIGHTENING MACHINES

JOSHUA BIGWOOD & SON LTD.

Phone— 20352, 20686/7

WOLVERHAMPTON

Grams—Bigwood Wolverhampton

BRAYSHAW SALT BATH FURNACES

FOR THE HEAT-TREATMENT OF ALUMINIUM ALLOYS

Aircraft and automobile manufacturers desirous of attaining the utmost uniformity in the heat-treatment of aluminium alloys should allow us to submit designs and schemes from our long experience of Salt Bath practice. Brayshaw Salt Bath Furnaces give most efficient and accurate results and are planned with suitable fitments and accessories to facilitate handling of work and to maintain a high output

BRAYSHAW FURNACES & TOOLS LTD., BELLE VUE WORKS, MANCHESTER, 12

Telephone : EASt 1046 (2 lines) *Telegrams* : HARDENING, MANCHESTER

Sterling

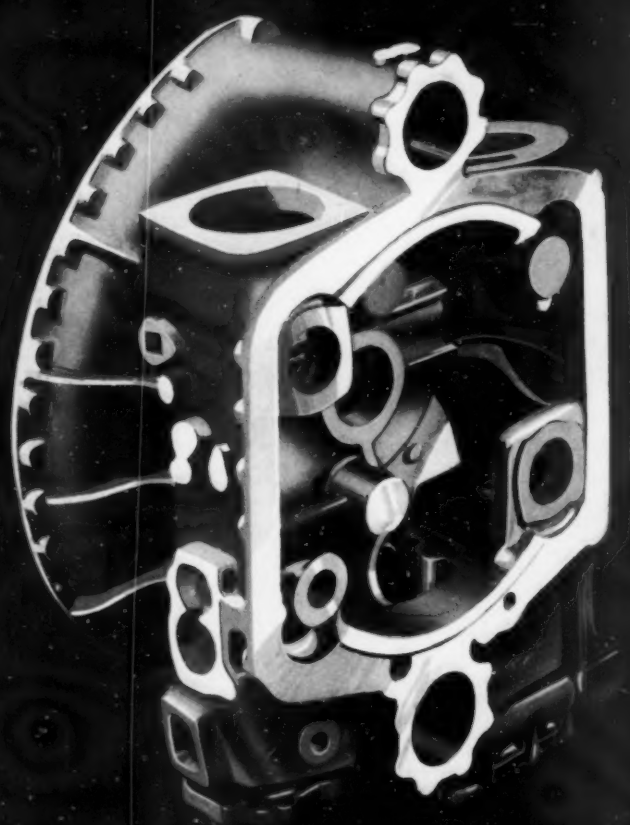


Illustration shows casting in "Elektron" of the Front Supercharger Casing for the Napier "Dagger" engine. Photograph by courtesy of D. Napier & Son, Ltd.

FOR SAND AND DIE CASTINGS IN

ELEKTRON ALUMINIUM

MAGNESIUM ALLOYS NORMAL AND HEAT TREATED

"ELEKTRON FORGINGS"

TELEPHONE COVENTRY 8035 (5 LINES)

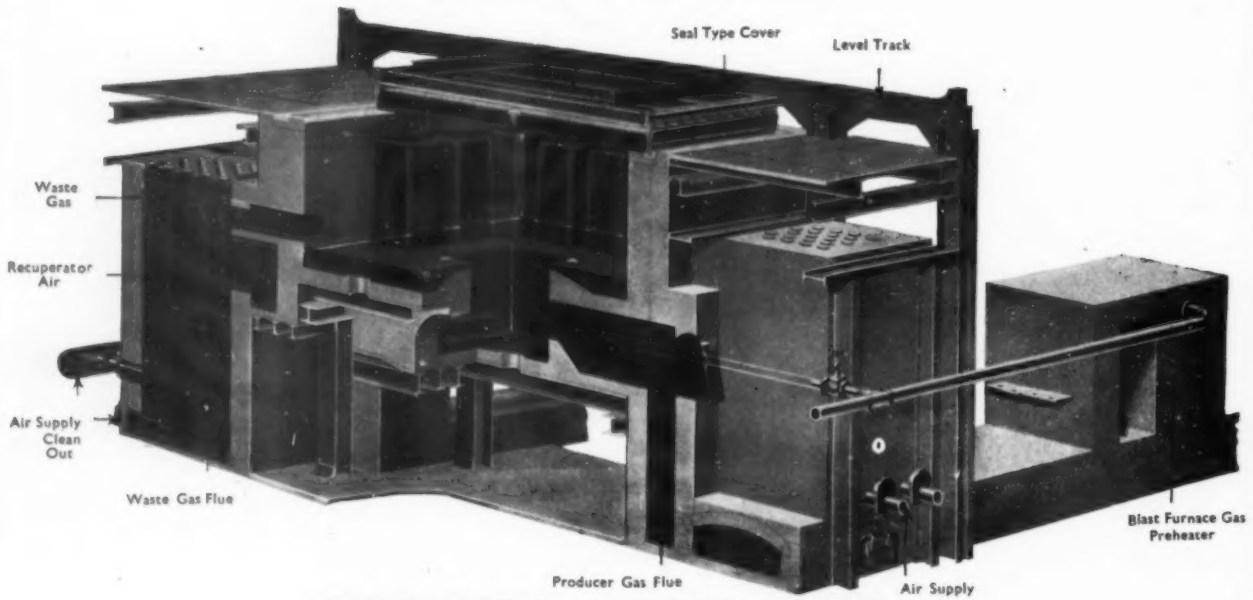
STERLING METALS LTD., COVENTRY

TELEGRAMS STERMET PHONE COVENTRY

T.G.S.

K.T.G.-AMCO RECUPERATIVE SOAKING PIT

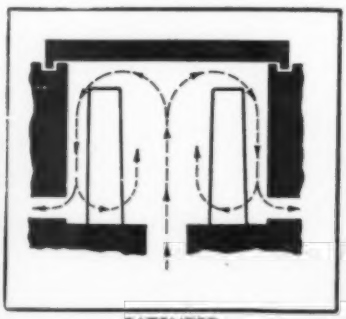
Patented and Patents Pending



OPERATING ADVANTAGES

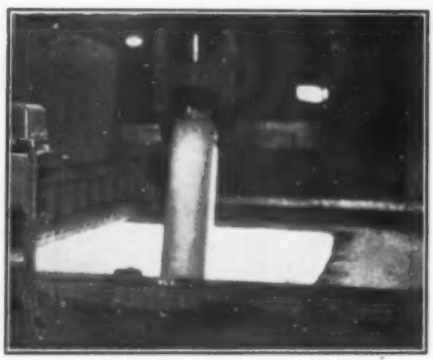
UNIFORM HEATING—controlled flame parallel with long axis of ingots : better steel, shorter cropping.
WASHING ELIMINATED—correct fuel application automatically regulated.
BOTTOM MAKING WEEKLY—saves coke and labour. ADDS UP TO ONE EXTRA HEAT DAILY.
INCREASED TONNAGE—charged capacity is increased up to 100% when compared with existing pits.
SEALED COVER—CRANE TYPE MOTORISED CARRIAGE.
Automatic fuel and air regulation with cover movements—saves fuel—speeds operation.

CONTROLLED HEAT CIRCULATION
character of scale controlled.
DEPENDABLE RECUPERATION.



PATENTED

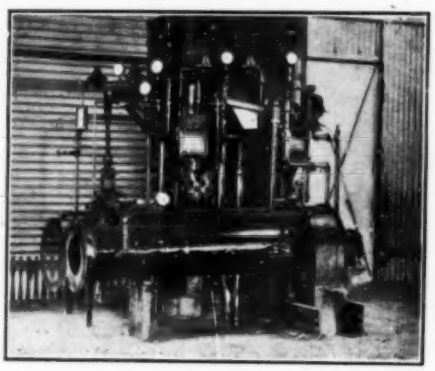
FUEL SYSTEM FULLY AUTOMATIC
draught control.
NO MANUAL ADJUSTMENTS.



Open Pit

KTG

USES ALL FUELS



Automatic Draught and Air Ratio Equipment

Embodies the best known combustion, metallurgical and mechanical practice.

WRITE FOR FULL PARTICULARS TO :

KING, TAUDEVIN & GREGSON LTD.

Furnace and Gas Plant Engineers,

Melbourne Chambers, Cambridge Street,

Telephone :
Sheffield 21753.

SHEFFIELD 1.

Telegrams :
"Pyro, Sheffield."

How MICROMAX POTENTIOMETERS CELEBRATE HER 25TH. ANNIVERSARY

This was good

and in its day was recognised as the world's standard —often imitated but never equalled.

But this is better

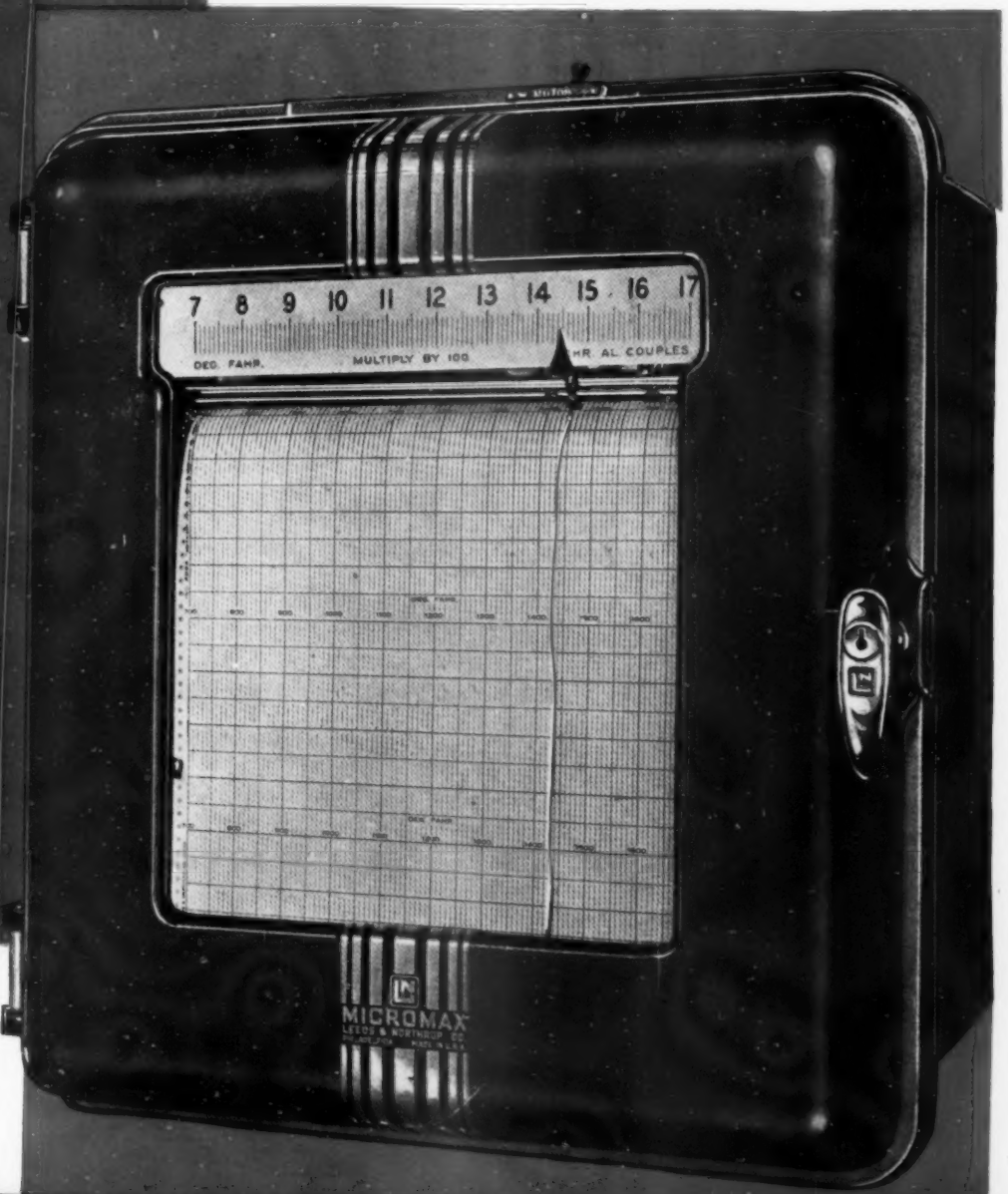
● Here is the new "MICROMAX" Silver Anniversary Model, the latest Leeds & Northrup recording-controlling potentiometer pyrometer. The product of over 25 years' specialised experience, it adds important advantages to a recorder already unmatched in industrial pyrometry.

● Single point or multi-point (up to 16) with records in one or several colours. Automatic controllers for any applications.

● "MICROMAX" pyrometers are extensively used in large British factories as well as abroad. Their accuracy is unaffected by wear on the balancing mechanism and is checked automatically and constantly throughout the day.

● Consult us on all your heat-treatment problems. In the L & N range: "Hump" Vapocarb hardening and "Homo" tempering furnaces, there is equipment that will give uniformly good results for minimum cost.

Write for Booklet N.33A.



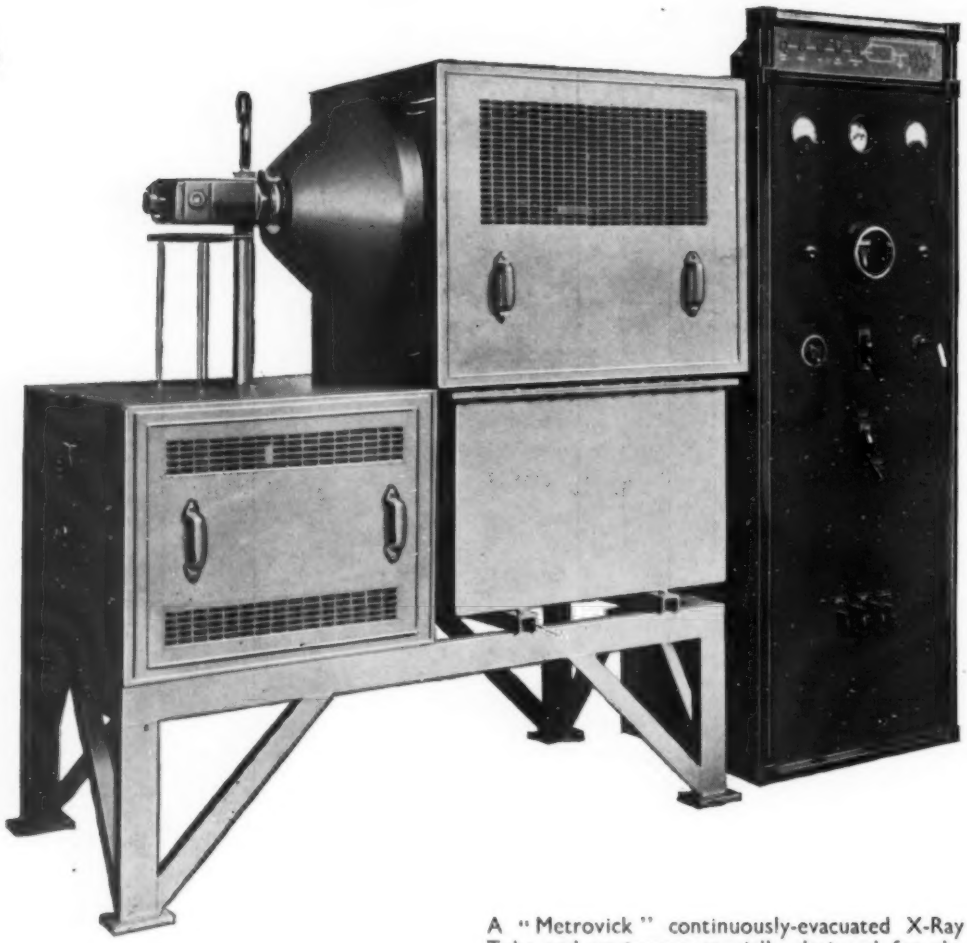
THE INTEGRA CO. LTD.

(INCORPORATED IN BELGIUM)

Representative and Manufacturing Licensee of the LEEDS & NORTHRUP Co.

183, BROAD ST., WORKS: 75-79, ISLINGTON ROW, **BIRMINGHAM 15**

CRYSTALLOGRAPHIC ANALYSIS of METALS



A "Metrovick" continuously-evacuated X-Ray Tube and equipment specially designed for the crystallographic analysis of materials.

It gives information respecting the molecular structure of materials not obtainable by other means and is of great use to the industrial research worker.

As supplied to many leading university and research laboratories throughout the country.

Low Maintenance and Repair Charges

Send your enquiries.

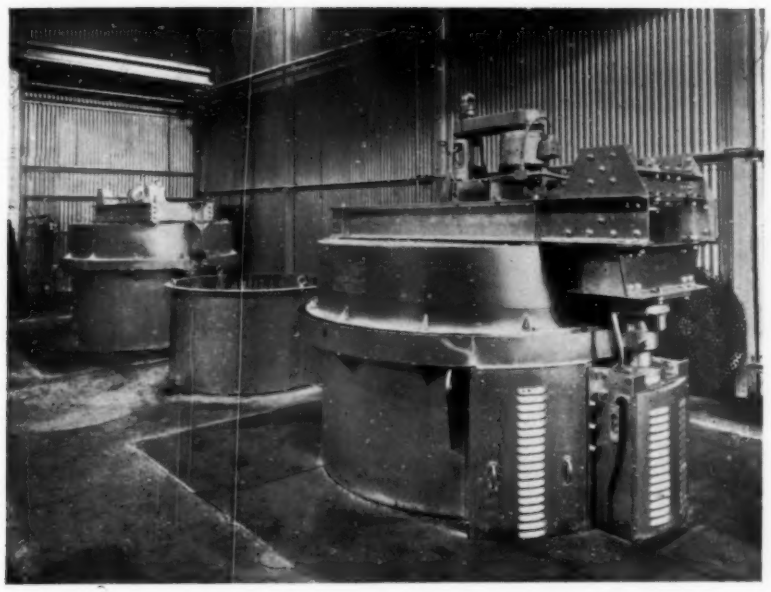
METROPOLITAN Vickers

ELECTRICAL CO., LTD.

TRAFFORD PARK ··· MANCHESTER 17.

C/R 901

EFCO Furnaces for the Light Alloy Industry



Typical EFCO vertical forced air circulation furnace for heat treatment of light alloy castings.

We are manufacturers of furnaces for the melting and heat treatment of aluminium and light alloys for the production of sheet, strip, extruded sections, forgings, castings, etc., and amongst the users of our furnaces are the following Companies:

James Booth & Co. (1915) Ltd.
The British Aluminium Co. Ltd.
Northern Aluminium Co. Ltd.
Reynolds Rolling Mills Ltd.
Reynolds Tube Co. Ltd.
Sterling Metals, Ltd.
J. Stone & Co. Ltd.
Birmetals Ltd.

EFCO

ELECTRIC FURNACE COMPANY LIMITED
ELECTRIC RESISTANCE FURNACE CO. LTD.
17 VICTORIA STREET, LONDON, S.W.1

TELEPHONE ABBEY 4171 (7 LINES) **TELEGRAMS ELECTRIFUR, PHONE, LONDON**

Lindum

GIBBONS FURNACES

The above illustration shows a Patent Gas Fired Furnace for heating non-ferrous metal billets for piercing.

Reliable results sought in heat-treating practice depend upon the proper combination of the man, the furnace, and the material. Good material is entitled to proper treatment in good furnaces, and both should have the services of good men. No two cases are alike, and no type of furnace has a monopoly on uniformity of heating or economy in operation ; for this reason we as specialists, design heat-treatment furnaces to suit your particular conditions and products ; in this way reliable results can be assured, with the utmost economy.

For all types of burners and small heat-treatment furnaces

write to our associated company:—

THERMIC,
Equipment and Engineering Co. Ltd.
Foundry Yard, Salmon St.,
PRESTON.

Telephone : - 3782 PRESTON
Telegrams : - THERMIC

GIBBONS BROS. LTD

DUDLEY WORCESTER

FAMOUS FIRMS WHO USE THE 'CASSEL' PROCESSES OF HEAT TREATMENT . . .

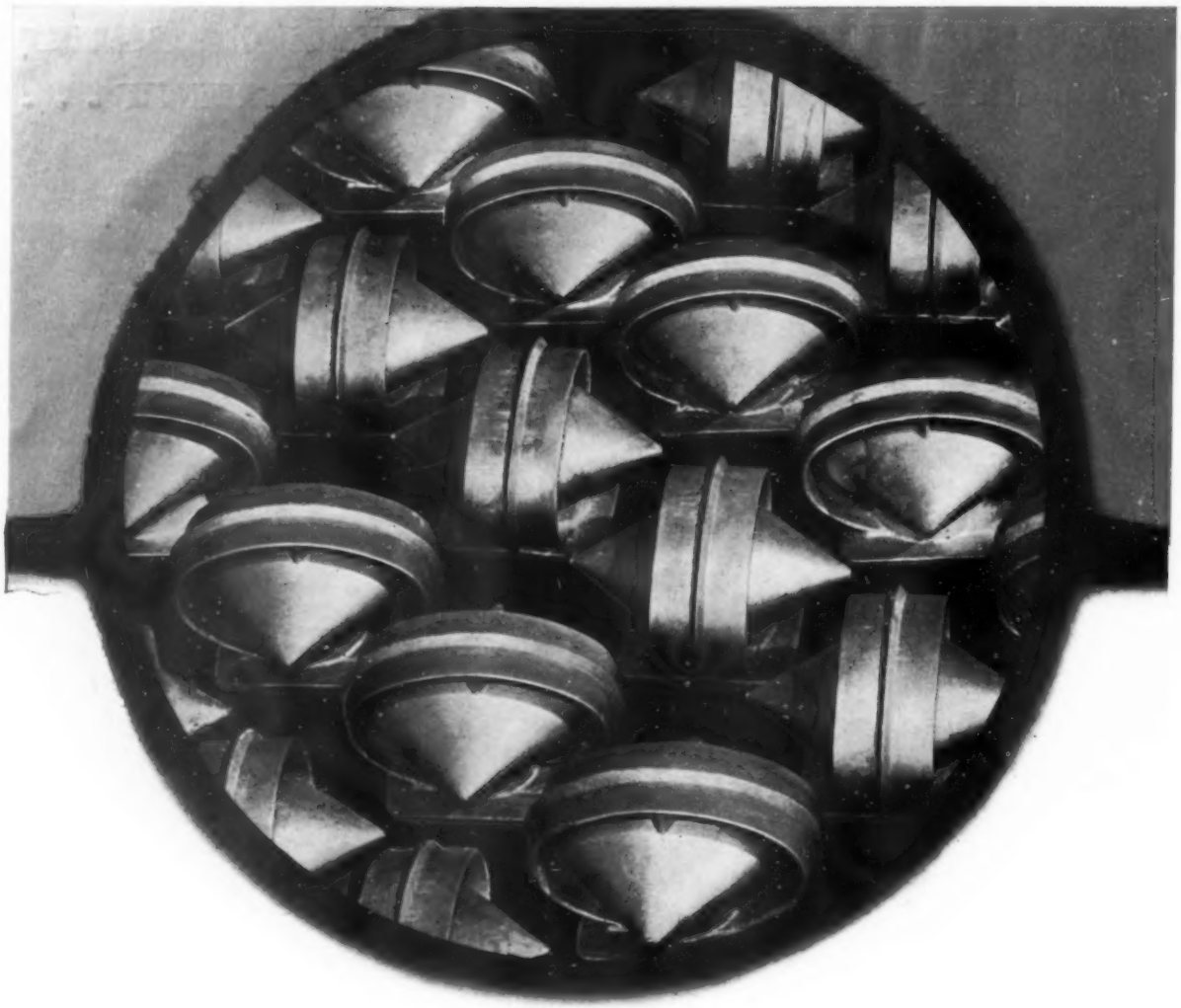
THE AUSTIN MOTOR COMPANY LTD.

The reputation of Austin Motor Cars is founded on dependability. It is, therefore, significant that 'Cassel' Processes are standard in the vast Austin Works for the Heat Treatment of vital steel components. The 'Cassel' 'Rapideep' Process carburises camshafts to a depth of 0.055 ins. and cyanide is used extensively for the Heat Treatment both of gears after carburising and of gears from alloy steels. If you are concerned with the manufacture of steel components demanding prolonged resistance to wear and tear, the 'Cassel' Processes will prove invaluable to you. Send for fully descriptive literature to-day.

'CASSEL' PROCESSES OF HEAT TREATMENT

IMPERIAL CHEMICAL INDUSTRIES LTD., DEPT C.6, IMPERIAL CHEMICAL HOUSE, LONDON, S.W.1.

M58



New business for the foundry —a better product for the customer

IT was obviously sound to cast these railway carriage roof ventilators in one of our Aluminium alloys instead of constructing them, as previously, from sheet in another metal—but only one foundry realised it, and they reaped the benefit—a first order of 1,420.

There is extra business waiting for you too. There are many jobs that would be better cast in Aluminium alloy—some of them may be passing through your foundry at this moment. See to it that *you* suggest casting them in Aluminium to the manufacturer lest someone else does.

We shall be pleased to send you full particulars of our foundry Aluminium alloys and invite you to consult our technical department for any assistance you may require. *Aluminium Union Limited, The Adelphi, London, W.C.2. Telephone: Temple Bar,* 7766.

ALUMINIUM UNION LIMITED

HIGH PURITY ALUMINIUM INGOT · FOUNDRY ALLOYS

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

★ The source of all matter extracted from this Journal must be duly acknowledged; it is copyright. ★

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
The Canadian Aluminium Industry .. *The Canadian aluminium industry goes back to 1899, when the construction of the Shawinigan Falls smelter was begun. Fabrication of the aluminium produced began in 1901. In the last few years production facilities have been greatly increased, and in this article the industry is briefly reviewed.*	205–207
Development in Empire Tungsten Production	208
British Shipping and Shipbuilding ..	209
Iron and Steel Institute Annual Meeting	210
Trade Mission to the United States ..	210
The Stelliting of Exhaust Valves and Valve Seats. By S. A. J. Sage .. *Modern materials have increased the utility of poppet-valve engines to meet the arduous conditions encountered in high-efficiency aero engines. One of these materials is Stellite, and in this article its application to valves and seats is discussed*	211–214
British Chemical Standards	214
Industrial Management and Production Control. By F. L. Meyenberg .. *The discussion of the time-study man and his task is continued in an endeavour to show the change since the days of Fred Taylor, and to point out the important work which still lies ahead.*	215–217
The Mechanism of the Reaction between Hydrogen and Carbon in Iron	217
The Influence of Some Special Additions on Certain Properties of Cast Iron	218
Metal-Sprayed Bearings for High-Speed Operations .. .. *Tests on sprayed-metal bearings in comparison with cast bearings are given, and the results discussed. Important developments in this field are indicated.*	219–220
Protection of Steel Against Corrosion	220
Strength of Marine Engine Shafting .. *The strength of marine engine shafting is considered, based on experience and the result of thorough investigation into the causes of failure. Extracts are given from a recent paper by Dr. Dorey on the subject.*	221–222
Contact Corrosion of Stainless Steel. By John Arnott, F.I.C. .. .. *Local attack on some types of stainless steel in contact with apparently innocuous non-metallic substances, under wet conditions, is discussed.*	223–224
Some Aspects of the Non-Ferrous Metals Trade. By Gilbert Evans.. *The increasing demand for non-ferrous tubes is reflected in the many installations of plant recently put into operation or in course of construction. British plant for this purpose is finding increasing interest abroad. Some new installations are discussed.*	225–226
Per Capita Output and Labour Planning	227–228
Surface Rolling of Aeroplane Propellers	228
Soviet Ferrous Metallurgy under the Third Five-Year Plan. By a Special Correspondent .. .. *The progress achieved from previous construction schemes in the U.S.S.R. is referred to, and an outline given of a new five-year scheme recently presented to further extend ferrous metallurgy in the Union.*	229–230
Recent Developments in Materials, Tools and Equipment. .. .. *Rotary Exhausters and Compressors. A Lubricant for Rubber.*	231–232
Reviews of Current Literature	233–234
Some Applications for Heat-Resisting Nickel Cast Iron .. .. *Under modern conditions the usefulness of ordinary cast iron for heat-resisting purposes is strictly limited, and the use of alloy cast irons is necessary to ensure satisfactory service. Some alloy cast irons for this purpose are discussed.*	235–236
Business Notes and News	237
Metal Prices	238

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "*Kenpred,*" *Manchester.* *Telephone: Central* 0098.

STEIN

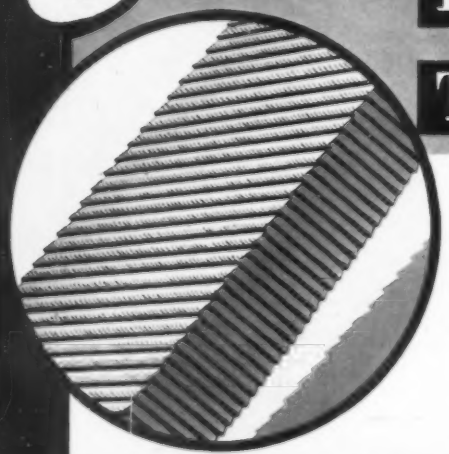
Chrome & Magnesite REFRACTORIES

STEIN Chrome and Magnesite Refractories are available in five brands. While STEIN KM and STEIN DIKRO, respectively burned and unburned chrome-magnesite, both offer high resistance to slags, the former has outstanding under-load strength and volume stability at high temperatures and the latter remarkable spalling resistance. STEIN CHROME, burned chrome brick, is chemically neutral, resisting acid and basic slags, and STEIN MAG, a burned magnesite, shows superior under-load and anti-spalling properties. STEIN DIMAG is an unburned magnesite brick, having high resistance to destruction by spalling or corrosion by iron slags, has high mechanical strength, and does not disintegrate.

JOHN G. STEIN & CO. LTD.
BONNYBRIDGE, SCOTLAND

THE "Sandblast"

FINISH means TOOTH-SHARPNESS



AND

MORE METAL REMOVED IN A GIVEN TIME

Sandblasting is a process whereby a jet of fine sand and water is directed at high pressure along the back on to the file teeth. This removes all the "fash" left by the chisels when cutting the teeth, and gives a clean sharp cutting edge with every tooth doing its work.

Add to this the high base quality of the steel which we use—steel melted, forged and rolled in our own Steel Mills—and you get the reason why SANDERSON FILES are just that little bit better.

We make every shape and size of File and Rasp

Our deliveries are good and our prices competitive

SANDERSON BROTHERS & NEWBOULD LIMITED
SHEFFIELD ENGLAND

STEEL & TOOL MAKERS SINCE 1776

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

APRIL, 1939. VOL. XIX, No. 114.

The Canadian Aluminium Industry

Production Plants in Arvida and Shawinigan Falls

The beginning of the aluminium industry in Canada goes back to 1899, when the construction of the Shawinigan Falls smelter was begun, the first ingots having been cast two years later. Fabrication of the aluminium produced began in 1901. In the last few years production facilities have been greatly increased. The Canadian market for aluminium products is relatively small, and the major part of this increased production is for export.

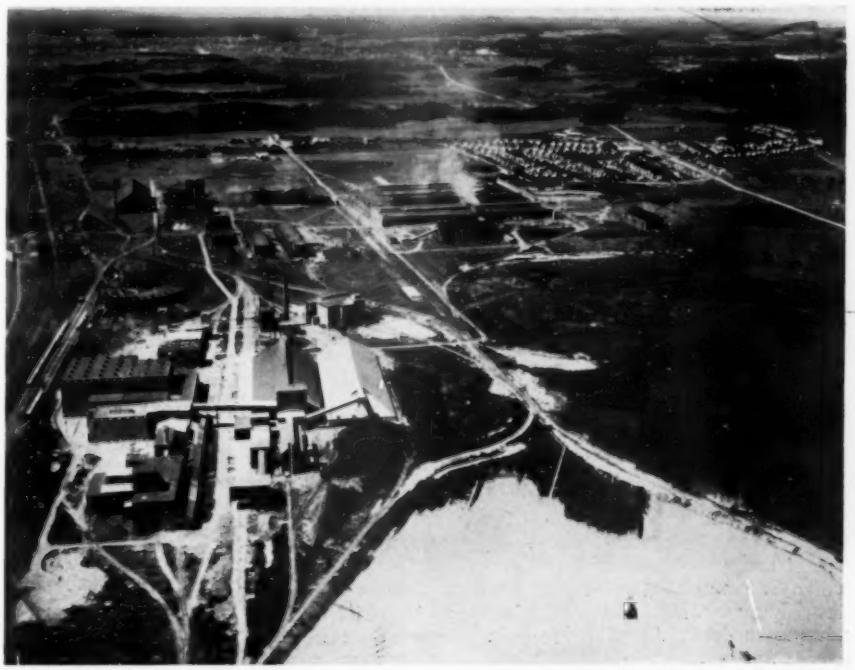


Photo by Canadian Airways, Ltd.

Arvida works of the Aluminium Company of Canada, Ltd. The town of Arvida is depicted on upper right of illustration.

THE reduction of aluminium ores and the production of primary aluminium in Canada is confined to Quebec, in which province the Aluminium Company of Canada, Ltd., operates an ore treatment plant at Arvida and reduction plants at both Arvida and Shawinigan Falls. At the Arvida plant aluminium oxide is made from British Guiana bauxite, and aluminium ingot produced in the two reduction works. The company named operates also fabricating plants at Shawinigan Falls, P.Q., and Toronto, Ontario. Bauxite from British Guiana is washed and dried before being shipped. At Arvida it is treated by the Bayer process to remove impurities, and pure aluminium oxide is recovered. Cryolite, necessary in the production of the metal, is imported from Greenland. A very large amount of electrical energy is utilised in the production of new aluminium metal from bauxite concentrates.

The beginning of the aluminium industry in Canada goes back to August 14, 1899, when construction of the Shawinigan Falls smelter was begun, the first ingots having been cast two years later, on October 20, 1901. Actually, this plant is the oldest established aluminium smelter now operating in North America, although it was preceded by one or two others which have now been dismantled.

Since the building of the first smelter at Shawinigan Falls, the company, formerly known as the Northern Aluminium Company, Ltd., has followed a policy of building plants with production capacities considerably greater than domestic consumption. The Canadian aluminium industry has sufficient reserves of ore to enable it to operate at full capacity for many years.

The great plant at Arvida, in the Lake St. John area of Quebec, one of the largest in the world, was created in 1926. The establishment included an aluminium smelting plant, a plant for purifying cryolite, a plant for making the carbon electrodes for the electrolytic smelting of the metal, and an ore refining plant. Arvida is a model town, complete with homes, schools, churches, and recreational facilities, constructed on a high plateau on the south bank of the Saguenay River. To handle incoming raw materials and outgoing finished products, terminal facilities were acquired at Port Alfred, 20 miles distant, on Ha ! Ha ! Bay, at the head of deep-sea navigation on the Saguenay River. A railroad was purchased and reconstructed to connect Arvida with the port, whilst at the same time hydro-electric power was developed in huge quantities in the district.

The bauxite used at Arvida is mined by a subsidiary of the Aluminium Company of Canada, Ltd.—namely, the Demerara Bauxite Company, Ltd. The deposits lie as much as 100 ft. below the surface at the British Guiana mines, and vary in thickness from a few feet to 25 ft. or more.

They are very hard, and are broken by blasting. The material, after crushing, washing and drying at Mackenzie, 10 miles from the deposits, is shipped directly by ocean-going vessels to Port Alfred, P.Q., 3,223 miles distant.

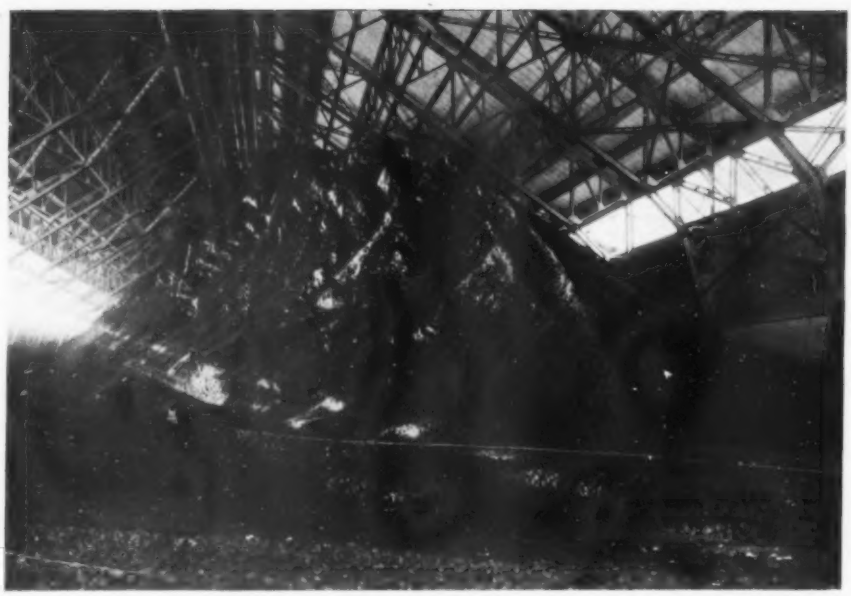


Photo by Edwin Levick

Petroleum coke in storage at Arvida.

Port Alfred is at the head of deep sea navigation on the Saguenay River. From here the bauxite is shipped 20 miles by rail to Arvida. The necessary petroleum coke is imported from the Gulf of Mexico or from ports on the Great Lakes, whilst cryolite is brought in from the Danish Government deposits at Ivigtut, near the Arctic Circle in Greenland.

Canada contributes to this important electro-metallurgical industry a fundamental "raw material"—namely, hydro-electric power—and in the great Arvida industry, nearly one and a half times as much electrical energy is used as the average load of the whole of Montreal, which is Canada's largest metropolitan area, containing not only many homes, but a very large number of important manufacturing industries. It is calculated that the electrical energy consumed in making 1 ton of aluminium would supply the average home in Canada with electric light, heat and power for 28 years, or would make no less than 18 tons of newsprint paper. The total consumption of power by the Aluminium Company of Canada, Ltd., places that concern as Canada's largest single consumer of electricity.

The smelting of aluminium is an electrolytic process in which the current passes through a solution of aluminium oxide dissolved in molten cryolite, and deposits molten aluminium at the negative electrode. The furnaces used are rectangular shells made of steel plates and lined with a paste made of ground metallurgical coke and tar which is baked to obtain the necessary hardness. This lining may be in one piece or composed of separate blocks. In either case, the lining is a good conductor of electricity and serves as the negative electrode to which the current is brought by metal electrodes buried in the lining. The positive electrode is also of baked carbon. This is suspended in the bath of aluminium oxide dissolved in cryolite. The anodes may be of the multiple type or the single or Söderberg type. A furnace using multiple anodes may have 12–18 of them, carbon blocks measuring about 15 in. in each dimension. In the Söderberg type of furnace there is but one anode so large as almost to fill the steel shell below it. Such a large single electrode is formed continuously by adding a mixture of metallurgical coke and tar, in paste form, to the upper end of the electrode. This paste is held in position by a metal shell, and as it slowly approaches the molten cryolite it becomes baked to a sufficient degree of hardness by the heat from the furnace below.

The cryolite flux is first treated to remove metallic sulphides and carbonates. To start a furnace, a large quantity of pulverised and purified cryolite is placed in the carbon-lined steel shell and heated to the molten stage by the passage of a heavy electric current. The carbon blocks are then extended into the bath (the temperature is about 1,000° C.), and the furnace is ready to receive the aluminium "ore."

The electric current, in some cases amounting to 40,000 amperes, or nearly 400,000 times as much as flows through an ordinary 25-watt house lamp, enters the furnace through the carbon blocks, passes through the cryolite, and leaves by the carbon lining.

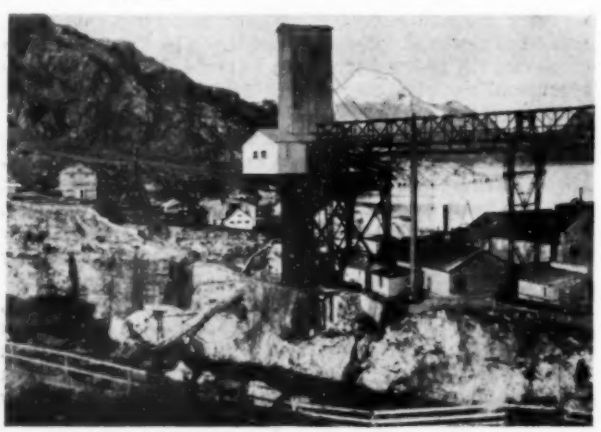
Concentrating Bauxite

Bauxite is concentrated by dissolving in a hot solution of caustic soda under pressure and subsequent filtering and precipitation as aluminium hydrate. The aluminium hydrate is converted to aluminium oxide by heating. It is charged periodically into the electric furnaces and dissolves in the molten cryolite. The aluminium and oxygen are separated by the action which takes place within the furnaces. By the intermittent tapping of each of the hundreds of electric furnaces used, there is a continuous

Chute-à-Caron powerhouse, operated by Aluminium Power, Ltd. The installed capacity of this generating station is 260,000 h.p.

Photo by A. C. Johnston

Cryolite mines at Ivigtut, Greenland.



production of metal at each smelter. The aluminium establishment at Arvida is self-contained, but the one at Shawinigan Falls receives its carbon blocks, Söderberg paste, treated cryolite and refined aluminium oxide from Arvida.

Aluminium fabrication in Canada dates back to 1901, when a wire mill was built at Shawinigan Falls. Until 1915, all of the aluminium wire and cable produced in Canada was fabricated from imported aluminium rod. Since the construction in that year at Shawinigan Falls of a rolling mill for rolling rod from aluminium wire-bar, all the operations for the production of aluminium wire and cable from the ingot have been performed in Canada. More recently, equipment has been installed for the drawing of rod and tubing.

The Toronto fabricating plant of the Aluminium Company of Canada, Ltd., was erected in 1912, and a foundry for producing aluminium castings commenced operations in 1914. In 1916 the sheet-rolling mill began making aluminium sheet from aluminium rolling slabs, many of which were imported until 1922, when additional melting equipment was installed, permitting all of the operations for the manufacture of aluminium sheet from the raw ingot. A screw-machine products division was put into operation in 1925. Three years later a foil mill started rolling aluminium foil, and in 1930 a mill for making seals and caps from aluminium sheet commenced production. Cooking utensils were made at the Toronto plant as early as 1913, but in 1931 this division was taken over by Aluminium Goods, Ltd., a subsidiary of the Aluminium Company of Canada, Ltd., formed especially to manufacture and sell this type of product.

In recent years the use of strong alloys of aluminium requiring heat-treatment has developed to a moderate extent in Canada, and the Aluminium Company of Canada, Ltd., has installed equipment at its Toronto and Shawinigan works to supply such materials.

Twenty other factories in Canada not connected with the Aluminium Company of Canada, Ltd., use aluminium as their main raw material and work it into finished products, such as cooking utensils, wire, cables and various specialities. However, the Canadian demand for aluminium in its various fabricated forms and as ingot corresponds to only a small percentage of the productive capacity of the smelting plants at Arvida and Shawinigan. The bulk of the Arvida and Shawinigan production of raw metal, therefore, must be sold outside Canada. In addition, the plants of the Aluminium Company of Canada, Ltd., which manufacture aluminium sheets, strips, rod, tubing and cable, have capacity to supply export markets. All these products of the Aluminium Company of Canada, Ltd., are sold outside of Canada by its associated company, Aluminium Union, Ltd.

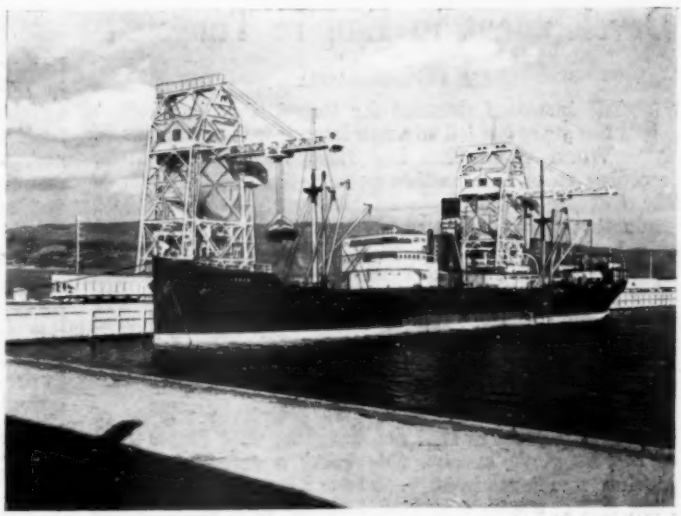


Photo by A. C. Johnston

Unloading British Guiana bauxite at Port Alfred, Quebec, for transhipment to Arvida.

Photo by A. C. Maier

Removing overburden of soil and sand, sometimes 100 ft. deep to expose bauxite beds.

Machine Building

The Donets Basin has become an important centre for the construction of heavy plant and machinery. The Stalin heavy machinery works at Kramatorsk manufactures blast and open-hearth furnaces, blooming mills, and all kinds of rolling mills. The stamping department of this plant has an enormous output. At Kramatorsk is also the Orjonikidze machine building works; at Gorlovka is a plant producing mining machinery for the entire coal industry, and in Voroshilovgrad is the locomotive works, where are produced the powerful FD and JS locomotives. A number of chemical factories have also been built. The output of chemicals in the Donets Basin to-day is twelve times greater than formerly.

Mining bauxite near Mackenzie in British Guiana.

Development in Empire Tungsten Production

THE increased demand for tungsten during the last few years has led to a new interest in Empire sources. World production has risen rapidly since 1932, according to an informative note in the current issue of *The Bulletin* of the Imperial Institute. In 1937 world production amounted to about 34,500 long tons (reduced to a basis of 60% WO_3), as compared with the former record of 31,400 tons for 1918. Of the 1937 total China contributed about one-half, and the British Empire roughly one-quarter. The persistent fear that the Chinese supplies might be cut off as a result of the Sino-Japanese war has undoubtedly had a powerful influence on the industry.

Burma is the most important Empire producer of tungsten ores, and in 1937 accounted for 67% (4,998 tons) of the Empire's output, this being a record over the previous maximum in 1917. The ore is essentially wolframite, and is usually obtained together with tinstone, the region in which it occurs being a continuation of the Malayan tin belt, although distinctive in its tunsten mineralisation. During the last three years Malayan production has decreased largely owing to the falling off of supplies from the Kramat Pulai scheelite mine.

Australia showed a big increase in production in 1937, with a total of 738 tons of concentrates, and in 1938. This amount had been exceeded by the end of September, so that Australia is likely to displace Malaya as the second Empire producer. The main developments have been in the northern territories and Tasmania. In the former state there has been considerable activity in wolfram mining round Alice Springs, where there are three fields, Hatches Creek, Wanchope and Mount Hardy.

In north-eastern Tasmania tin-tungsten mining has been active in the Avoca field, where it is estimated that since 1872 no less than 2,000 tons of wolfram concentrates have been produced. At the Storey's Creek mine, the present largest producer, considerable improvements have been made to the plant, and wolfram lodes, previously neglected when tin was the principal mineral sought, are now being developed. In 1937, 11,736 tons of ore were milled and produced 239 tons of wolfram and 27 tons of cassiterite. The Aberfoyle mine, in the same field, is essentially a tin mine, million 250 tons of ore a week, which averages 1¼% tin and 0·2% tungstic acid, the production of wolfram in 1937 being 35½ tons. Another important development in Tasmania has taken place on King Island, in the Bass Strait, where scheelite mines at Grassy have been reopened. Queensland has several small producers in the Cairns district, and in 1937 produced 98 tons of wolfram and two tons of scheelite concentrates.

In New Zealand the most important source of scheelite is in the Glenorchy district at the head of Lake Wakatipu in north-western Otago. The industry flourished here during the war, but subsequently mining was negligible until the recent interest in tungsten called attention to the field in 1934. Since then most of the old claims have been reopened and prospected further along the lodes.

Tungsten mining has developed considerably in Southern Rhodesia during the last four years, and in 1938 production to the end of November reached the record figure of 278 tons of concentrates with a record production during that month of 50·93 tons. While several mines have contributed to the production most of them are still in the development stage or have yet to perfect their concentration processes. Prior to 1936 tungsten production in the Union of South Africa was almost negligible, the highest recorded output being 17 tons of concentrates in 1918. In 1936, however, production rose to 29 tons, in 1937 to 34 tons, and in the first eleven months of 1938 to 102 tons. The principal source is scheelite got by individual diggers in the Steinkopf native reserve, Namaqualand, from small quartz veins carrying tourmaline and scheelite and associated with pegmatites.

Tanganyika is a new addition to the ranks of the smaller Empire producers, which include South-West Africa, Nigeria and Uganda. Wolfram was first discovered there in 1934 near the Karagwe tinfields, and to the end of October, 1938, about 27 tons were produced. Output is from the Kibanda claims, situated 18 miles by a rough motor-track from Muronga, where wolfram occurs in quartz veins and greisens in a small granite cupola, some sections of the reefs averaging about 2% wolframite.

Non-Ferrous Metal Smelting and Refining

Canada occupies a prominent position among world producers of the non-ferrous metals. In 1937 she stood first in nickel and in platinum metals, which are derived almost entirely from nickel-copper ores. She ranked third in production of copper in all forms, and fourth in smelter output of the metal. In both mine and smelter production of lead Canada was surpassed in that year, in order of output, only by the United States, Mexico and Australia. In output of zinc in all forms the Dominion was exceeded only by the United States, and in output of the refined metal by the United States, Belgium and Germany. As a gold and silver producer Canada stood third, while she was fourth in output of aluminium.

Non-ferrous smelting and refining ranks first among Canadian manufacturing industries in gross value of production and second only to pulp and paper in capital employed. Central electric stations, which have a higher capital investment than either, are not now classified as a branch of manufacture. The non-ferrous smelting and refining industry, as defined by the Dominion Bureau of Statistics, comprises those firms engaged primarily in the smelting of non-ferrous ores or concentrates and the refining of metals recovered therefrom. In 1937 the gross value of its products totalled $318,278,000, while the capital employed amounted to $162,696,000. The gross value of production was the highest on record, and compared with $229,737,000 in 1936.

The estimated cost of ores, concentrates and other material treated in the industry rose from $137,857,000 in 1936 to $191,303,000 in 1937. Fuels and electricity purchased increased from $12,613,000 to $14,607,000; and chemicals and other process supplies from $7,989,000 to $10,559,000. The number of employees rose from 10,015 to 11,570, and the salaries and wages paid from $14,346,000 to $17,990,000. The net value of production (or the value added by processing) increased from $71,276,000 to $101,807,000.

Refined products of the non-ferrous smelting and refining industry in 1937 included gold, silver, copper, lead, zinc, aluminium, cobalt, cadmium, selenium, tellerium, radium salts, uranium compounds and sulphur. Other end-products of individual plants or companies were copper-nickel matte, cobalt salts, nickel, and cobalt oxides, arsenious oxide, sulphur in sulphuric acid, platinum metals residues, silver-sulphide, silver-bismuth bullion, zinc dust, zinc oxide (fume), blister and anode copper, and copper matte. The main source of the Canadian gold production is outside this industry, in the gold mines of Ontario, British Columbia, Quebec and other provinces, though a considerable output comes from the copper-nickel industry.

New Hand Cleanser

A new hand-cleanser, known as Itoph, has recently been produced by General Products Corporation, Chemicals, Ltd., 50, Grosvenor Street, Manchester 1, which is claimed to be very effective for ridding the hands of dirty oil and the like. It is particularly suitable for removing the penetrating black oil from the pores without much effort, while, in addition, it can be used for cleaning metal work, etc. It is understood to contain no sand, acid or soda, and not to be in any way harmful to sensitive skins. It is sold in tins, and 7 lb., 14 lb., 28 lb., 56 lb., and 112 lb. buckets; in addition, tins of the cleaner are available which are specially designed for use in works.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

British Shipping and Shipbuilding

BRITAIN'S trading structure, which has been patiently built up through many generations of merchants, is so delicate that efforts to weaken the structure, by means of disturbing gestures endangering peace, are probably engineered as a competitive weapon, and, for this reason stronger measures should be adopted to preserve fair play in the world's markets for Britain's manufacturers. By many subterfuges of her competitors Britain has allowed valuable business to go elsewhere. The decline in mercantile shipbuilding activity may be mentioned as one instance only, but it is a direct result of the disastrous effect of the depression in overseas trade on shipping. Shipping depends almost exclusively on world trade and, with the highly organised systems in operation designed to prevent trade, it is bound to suffer.

The shipbuilding industry, like the other principal industries, finds itself at a distinct disadvantage in competing for such marine vessels as shipowners may desire. It is burdened with heavy charges for social expenditure, high wage rates and high cost of important raw materials, in comparison with many of its foreign competitors. But it is not so much the high relative costs in this country that have needed attention as the extent of subsidies supplied by foreign governments which made it possible for them to build ships at prices which are regarded as being below cost. Fortunately, the adoption of a definite policy in shipping and shipbuilding, recently announced by the Government, in the form of special grants and subsidies, though somewhat belated, will tend to revive two industries which are of vital importance in national defence, and also have a big influence on trade.

Shipping has been one of the most important occupations in England since very early times, and it has experienced many fluctuations. The first shipping code dates back to the reign of Richard II, and in Magna Charta itself the Forty-first Article lays it down that all merchants shall have safe conduct to go out of or come into England, and to stay there. To pass either by land or water, and to buy and sell by the ancient and allowed customs without any civil tolls. Restrictive legislation against foreign shipping, however, was soon initiated and remained the settled maritime policy for nearly 500 years. The first Navigation Act, passed in 1381, was the signal for a rapid succession of laws designed to favour the home trader and penalise the foreigner. Legislation along these lines was carried to absurd lengths, just as it is, in these supposed more enlighted days, in some countries overseas. In the 17th century such Acts, notably, those of 1646 and 1651, were principally directed against the Dutch, and those specially intended to preserve to British shipowners and overseas traders the commerce of the American plantations, bore a general application. Cromwell's shipping legislation, however mistaken it may appear to modern eyes, was a great constructive policy, and it was not only maintained intact, but confirmed many years after the England he represented had changed. Not until 1849 were the Navigation Laws repealed, and not until 1854 was the coasting trade of the United Kingdom thrown open to the ships of every nation. Since that time shipping legislation has been designed more with a view to safeguarding life and property at sea than to favour the shipowners, and for nearly three generations British shipping has been entirely independent of Government subsidy or subvention; during this time it has been called upon to justify its existence on an economic basis. Not all nations copied the British example, but the repeal of the Navigation Laws undoubtedly relaxed their sea codes. The United States of America followed the British lead immediately, excepting in respect of her coastwise trade which even to-day is reserved to her own ships.

Recent years has seen a considerable change in the attitude of many foreign governments to shipping; the growth of a desire for self-sufficiency has increased the amount of shipping under the flags of other countries, and, at the same time, tended to reduce the value and volume of world trade. In order to maintain vessels in operation in the face of keen competition for cargoes, resulting from the new conditions, many methods have been adopted which are contrary to what was regarded as the usual custom. Political considerations have been the predominating feature in some countries, and British shipowners have been called upon to compete against subsidised foreign competitors, and in consequence the industry, which is of such vital importance to the nation, has been carrying on business against heavy odds. The decision of the Government to give financial support to British shipowners, in the form of subsidies, will counteract the disadvantages under which they have been operating for many years, and place British shipping in a better position to meet competition. The decision, which also includes grants towards the cost of new vessels, is an important step in the chequered history of British shipping and shipbuilding.

In connection with this Government decision the Board of Trade has recently announced that those shipowners who may have placed orders for ships since March 28, or intend shortly to place orders for ships, which come within the scope of the Government's proposals for assisting shipping and shipbuilding, are asked to notify the Board of Trade as soon as possible, should they desire to submit the orders for consideration under the Government's scheme. These preliminary notifications should contain the fullest particulars of the ships to be considered, as well as the name and address of the prospective owner. The decision has already given a considerable impetus to the building of new vessels, and although no exact figures are yet available regarding the number of ships ordered since the proposals were made, it is estimated that orders for nearly 20 ships have been placed with many shipyards on the Clyde, while orders for over 20 vessels have been placed with shipbuilding firms on the north-east coast.

The Lloyd's Register shipbuilding returns recently published reveal the plight this industry has reached, but it will be appreciated that the figures given somewhat exaggerate the position, because owners have been withholding orders for some time pending the Government's proposals for assistance. Owners and shipbuilders have been in close consultation for some time, and many of the orders, which have now been placed, were ready for placing as soon as the Government made known their intentions. The long-awaited decision will facilitate the development of British shipping and bring about a substantial measure of relief to the shipbuilding centres and to marine engineering firms as well as those who specialise in auxiliary machinery for marine vessels.

Trade Mission to the United States of America

THE Manchester Chamber of Commerce has decided to send a mission to the United States of America in May. The members are Colonel W. A. Grierson, D.S.O., D.L., and Mr. E. Raymond Streat, C.B.E. The visit is to be made under the auspices of the Macpherson Fund. It is the opinion of the Chamber that after Governments have made a trade agreement the obligation lies on the commercial communities of the two countries to establish contact with one another in order to examine the new conditions, and to make sure that every possibility of increased trade, in all directions, is being fully exploited. Individual firms do this in the normal course of their business, but there is also scope for inquiries of a more general character to probe possibilities which might not be of interest to individual firms already in contact, and which might entail the making of new contacts. In addition, there are steps which can be taken by organised bodies which are hardly open to individual firms, and it is the hope of covering all the ground which is the aim of this mission.

It is not anticipated that manufacturers in the United States will take exception to efforts on the part of the United Kingdom to make the best of the trade agreement, especially as experts recognise that at the most the agreement only offers opportunities for trade in British specialities and there is no likelihood of damaging competition with the domestic industries in America. The work of the mission is not confined to any particular activity, its aim will be to collect impressions of what the American market can take or might take in the way of Lancashire products, and place the results of their inquiries, including any friendly comments or criticisms from American sources, at the disposal of Lancashire firms on its return.

In addition to cotton, Manchester is no less an important centre of many other industries, notably engineering and chemicals, and the mission hopes to spread in America a fuller realisation of the many-sided resources of Manchester. It will emphasise the principles of trade, that it is essentially of a two-way character, and will offer the assistance of the Chamber to United States exporters. Problems regarding tariff and custom regulations are constantly cropping up in overseas trade, and the mission will endeavour to deal with some problems of this with a view to simplifying facilities for trade between the two countries.

The mission will receive the active assistance of Sir Owen Chalkley, H.M. Commercial Counsellor at the British Embassy in Washington, and Mr. Godfrey Haggard, H.B.M. Consul-General in New York, through authority given them by the Rt. Hon. R. S. Hudson, M.P., Secretary to the Department of Overseas Trade. The New York representative of the Manchester Ship Canal Company, Mr. George M. Massey (The Port of Manchester, 89, Broad Street, New York, N.Y.), is giving every possible assistance in America, and is receiving communications on behalf of the mission prior to their arrival. The Mission will sail from Southampton on May 3, and it is expected to spend three or four weeks in America. The exact time schedule and movements of the delegates are, to some extent dependent upon the engagements made on their behalf, but visits to Washington and Boston are more or less fixed, though the dates are left open, and visits to other centres will doubtless be arranged.

Mr. F. J. Tonks

Many readers will learn with regret of the death of Mr. F. J. Tonks, chief metallurgist of High Speed Steel Alloys Ltd., Widnes. Mr. Tonks had been head of the Technical Staff of this Company since it was formed in 1914 and contributed very largely to its development. He had been ill for some time but the end came rather unexpectedly.

Iron and Steel Institute

THE annual meeting of the above Institute will be held in the Lecture Theatre of the Institute of Civil Engineers on May 3—5, inclusive. In addition to the general business meeting, the following reports and papers will be presented for discussion :

Special Report, No. 25.—" Eighth Report of the Heterogeneity of Steel Ingots." Being a report by the Joint Committee of the Iron and Steel Institute and the British Iron and Steel Federation to the Iron and Steel Industrial Research Council. The report will be introduced by the chairman of the Joint Committee, Dr. W. H. Hatfield, F.R.S., and several sections will be presented for discussion, including Section II, " Segregation in Steel," by J. H. Andrew, H. T. Protheroe, R. T. Percival and A. J. MacDougall ; Section VI, " Second Report of the Oxygen Sub-Committee " ; Section III, " Oxygen Determinations on a Series of Bath Samples taken from an Acid Open-hearth Furnace," by G. E. A. Bramley, W. R. Maddocks and G. Tateson ; and, if time permits, Section IV, " The Delta Region in Carbon Steels," by Dr. Desch, F.R.S.

Special Report, No. 24.—" Second Report of the Alloy Steels Research Committee." This report will be introduced by the chairman, Dr. W. H. Hatfield, F.R.S., and the Sections to be presented for discussion are Section III, " The Sealing of Steels in Sulphur-free and Sulphur-containing Furnace Atmospheres," by A. Preece, G. T. Richardson, E. Simister and J. W. Cobb ; Section IX, " Second Report of Sub-Committee A, Thermal Treatment " ; Section XII, " The Intermediate Transformation of Alloy Steels," by W. T. Griffiths, L. B. Pheil and N. P. Allen ; Section XIII, " The Determination of the Transformation Characteristics of Alloy Steels," by N. P. Alien, L. B. Pheil and W. T. Griffiths ; and, if time permits, Section VII, " The Influence of High-frequency Electric Currents on the Properties of Steel," by A. G. Quarrell, R. Jackson and N. J. Petch.

Special Report, No. 26.—" First Report on Refractory Materials."

The following papers will be presented for discussion : " The Refining of Metal in the Basic Open-hearth Furnace. The Influence of Fluorspar on the Process," by W. B. Lawrie ; " A Study of ' Strain-Age-Hardening ' of Mild Steels," by C. A. Edwards, F.R.S., N. H. Jones and B. Walters ; " The Strain-Ageing of Dead-Mild Steel Strip Used in the Pressing of Automobile Bodies and Accessories," by J. W. Rodgers and H. A. Wainwright ; " Some Applications of the Spectrograph to the Quantitative Analysis of Ferrous and Non-ferrous Metals," by F. G. Barker ; " The Application of the Durville Rotatory Process to the Casting of Steel," by L. Northcott ; " The Rolling of Sections at the Appleby-Frodingham Steel Co., Ltd. ; and " The Influence of Carbonising Conditions on Coke Properties. Part II.—The Effect of Pressure, Temperature, Rate of Heating and ' Soaking ' on Coke Strength," by H. E. Blayden, W. Noble and H. L. Riley.

Other papers presented at this meeting include :" Nickel-Iron - Aluminium Permanent - Magnet Alloys," by W. Betteridge ; " The Effect of Nitrogen Additions and Heat-treatment on the Properties of High-Chromium Steels," by E. W. Colbeck and R. P. Garner ; " Notes on Slow Cooling of Ingots," by W. J. Rees ; " Interpretation of Thermal Curves and Some Applications to Ferrous Alloys," by T. F. Russell ; " Slag Inclusions and Acid Open-hearth Refining of High-Carbon Steel," by Haakon Styri ; " Notes on Discontinuities in the Resistance-Temperature Curves of Commercially Pure Iron and Steel," by C. Sykes and F. W. Jones ; and the Ablett Prize Paper, by H. Escher, " Ten Years' Development in Steam Engineering at the Port Kembla Steelworks, N.S.W., Australia."

The Annual Dinner will be held at Grosvenor House, Park Lane, London, W. 1, on May 4, at 7 for 7-30 p.m., under the presidency of the Rt. Hon. The Earl of Dudley, M.C., at which Admiral of the Fleet the Rt. Hon. Lord Chatfield, G.C.B., K.C.M.G., C.V.O., Minister for the Co-ordination of Defence, will be the Guest of Honour.

The Stelliting of Exhaust Valves and Valve Seats

By S. A. J. SAGE

Modern materials have increased the utility of poppet-valve engines to meet the arduous conditions encountered in high efficiency aero engines. One of these materials is Stellite, which, applied to valves and seats, withstands exhaust gases for long periods and resists wear. In this article the stelliting of these parts is discussed and reference made to faults and defects which may arise through lack of care in applying the Stellite.

Exhaust Valves and Seats

IN recent years there have been outstanding advances in engineering, especially in the aero engine and automobile engine sections. Mainly, this has been in the increase of power from the engines and in better methods of utilising this available power. This increase in power has been obtained by keeping the weight fairly constant and by increasing the overall efficiency or by the use of new materials.

Both these channels have been followed, so that not only has more power been obtained from the same swept volume but that the strengthening of the components to take this power has been by the utilisation of new materials brought forward by metallurgists in recent years.

Referring again to the rise in power of the engines. This in its train has brought many difficulties, not the least of which is the increasing wear of components and also the corrosion and erosion of those parts above the piston. Of these, perhaps the exhaust valves and valve seats have suffered most, and it can be shown that as the power of the engines has risen, so the design and material of these components have been modified.

The new ethyl petrols have been severe on these components, especially as they are working at temperatures near 800° C. This working temperature is the basic reason for ever changing the exhaust valve material, because there are few materials which have the necessary properties to function at these temperatures for lengthy periods between overhauls and to have a long working life. For instance, valve materials have changed from the original 3% nickel steel, through the silicon chrome and cobalt series to the austenitic heat-resisting steels, while the valve seat has changed from that of the original cast-iron head, through aluminium bronze to the more recent high expansion Ni-Cr-Man steel insert used with aluminium heads.

Applications of Stellite

Even these materials, while being able to withstand exhaust gases for considerable periods, have been improved so that wear is still more reduced and that longer periods may elapse before engines require overhaul. This latter achievement has been made by utilising a deposit of Stellite—a non-ferrous Co-Cr-W alloy, on the valve and valve seat faces.

This alloy has been found to withstand corrosion and erosion at high temperatures to a considerable degree. The tendency of this alloy to softening at high temperatures is also far less than that of high-speed steel—e.g., B.H. of 325 against 75 of the H.S.S. at 800° C.

Difficulties have been encountered as to the best method to apply Stellite to these surfaces. Arc welding can be and is utilised in applying Stellite to large areas of wearing surfaces, but owing to the size and shape of exhaust valves and seats, the oxy-acetylene method has been proved the most satisfactory for general use.

A departure from this method is that of the Wilcox-Rich Corporation. This method (English Patent 475,585) utilises a cleaning operation in a flux bath of borax of cryolite followed by the immersion of the component to be coated in a bath of the desired molten alloy. The component is then rotated to build up the coating and to get a more even layer. The thickness of this layer is dependent on the number of times the component is immersed in the liquid and also on the speed of rotation.

Fig. 1.—Blowholes found in poor stelliting, showing how their shape is connected with the finishing operation. ×8.

Methods of welding and bonding materials of this type to wearing surfaces are now recognised as "stelliting."

Oxy-Acetylene Stelliting

Returning to the normal process of stelliting by the oxy-acetylene method.

Rods of Stellite of about $\frac{3}{16}$ in. diameter are heated in the oxy-acetylene flame and applied to a heated surface of the steel. To do this, however, several precautions must be taken before any hope of a successful operation can be considered.

The rods of Stellite as supplied, are in the "as-cast" condition, and due to the method of manufacture there is a tendency for a hard skin to be formed. This skin, as would be expected, contains foreign matter associated with the casting operation and is sometimes so troublesome as to warrant grinding of every rod.

Scrupulously clean working benches are essential, because if the rods are placed in any dirt or grease the latter sticks to the rods and is transferred to the component, usually causing small blowholes or oxide, both of which detract from the quality of the finished article. It is also essential that the surfaces to be stellited should be scrupulously clean, this being done either by machining or scratch-brushing, followed by a degreasing operation to remove any cuttings, oils, etc., which, if allowed to remain, form a heavy carbon deposit when the components are pre-heated.

Acetylene as supplied is always in the dissolved condition, and is usually of high purity, but it is advisable to test the gas for sulphur content, as this element has a great effect on the final stelliting. To do this, a filter paper is saturated with a 2% Ag No. 3 solution and the acetylene allowed to blow on to the moistened paper. If any sulphur is present, it will form Ag 2 S, which can be immediately recognised by its dense black colour. If any cylinders

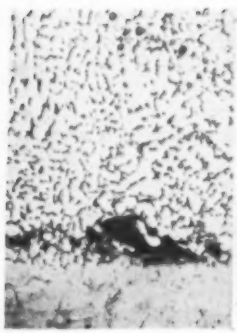


Fig. 2.—Stellite applied too cold, revealing poor joining. ×112.

Fig. 3.—Effect of applying Stellite at too high a temperature. ×56.

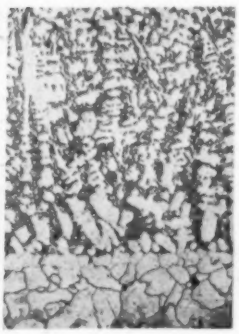


Fig. 4.—A good joint showing the use of proper temperature. ×112.

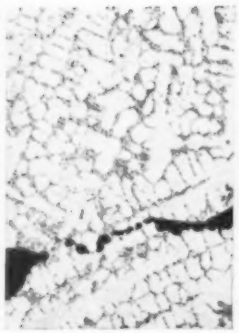


Fig. 5 and 6.—Globules caused by minute slag particles coagulating during the stelliting operation. ×112 ×375.

show this defect they should be immediately rejected as unsuitable for stelliting.

With Stellite an excess acetylene flame must be used. An oxidising or neutral flame causes fierce bubbling and frothing of the applied Stellite. The correct length of "feather" is about three times as long as the inner cone, a greater proportion than this causes carbon to be deposited on the faces to be stellited, and while this defect is not so detrimental as those caused by an oxidising flame, the speed of stelliting is affected, also poor bonding between the Stellite and the steel may be attributed to this excessively reducing flame. As exhaust valve and seat materials are usually of low heat conductivity and also that production methods seem to give the best results—i.e., that an operator who works on seats continuously gives a more satisfactory product than an operator who only does stelliting intermittently, preheating in a furnace is considered *sine qua non*. The apparatus for the stelliting operation comprises an oxyacetylene torch with a No. 3 nozzle, $\frac{3}{16}$ in. diameter Stellite rods, and a special revolving turntable on which is rested the seat or valve to be stellited. This table is driven by a low-speed induction motor geared down to give about 1 r.p.m. to the table, and is controlled by a foot pedal so that the operator can revolve his work either continuously or intermittently as he desires.

With a correct flame and a preheated component the stellite can now be deposited.

By playing a torch on to a small area of the steel a "sweaty" surface is formed. This is essential for obtaining a good bond between the steel and the Stellite, but must not be overdone, otherwise "washing" or erosion of the steel will result.

Once this "sweaty" surface has been formed, the flame and rod are so held that by small movements the rod is brought into the hottest part of the flame, a drop formed and applied to the steel, then moved back so that the flame is keeping the applied Stellite fluid and also preparing a fresh steel surface for more metal to be deposited. This action of the rod and flame soon becomes sub-consciously automatic with good stelliters, but new operators have to acquire the art of keeping both the rod and the work at a working temperature, so that the next molten drop will induce the Stellite already deposited to "flow" on to the adjacent "sweating" steel surface.

If the Stellite is applied too cold or too quickly without first preparing the steel surface, proper bonding will not occur, the junction then being very abrupt with no penetration, while foreign matter from the skin of the rod becomes entrapped in this junction between the steel and the stellite. This is due to the fact that if the steel surface is not correctly "sweating" the Stellite puddle will not flow, but will curve over, due to surface tension. Thus any oxide from the skin formed during the heating up of the steel and Stellite does not lift and flow forward as normally, but, still clinging to the surface of the depositing metal, is rolled over, chilled by the slightly colder steel, and so becomes permanently fixed just off the steel surface,

The first layer of Stellite "as applied" usually appear rough and irregular, and sometimes slag and small blows holes can be seen if the Stellite is inspected closely. As these are detrimental to the finished product, they must be removed. This is done by a finishing operation in which the blowpipe is used to remelt the deposited layer and by a circular movement fill up or bring to the surface all the small blowholes. Also, by whipping up the Stellite, all the small pieces of slag which had become entrapped in the solidifying metal are floated to the surface. With this operation, however, the effects of remelting seldom penetrate entirely through the Stellite to the bond, so that any defects in the bond caused through poor deposition cannot be rectified. Thus it is important that the deposition of the first layer must be correct, as the remainder of the stelliting depends on it for bond strength.

With this finishing operation, the cooling-off of the last portion is very important. Quick cooling leads to chilling of the Stellite with the formation of interdentritic porosity or shrinkage, so that finishing with the blowpipe is usually done with a circular motion, while the pipe is slowly withdrawn. This allows the liquid stellite to set evenly and solidly.

If this layer is not thick enough for the finished component, another layer of Stellite may be applied using a similar procedure. In this case, however, the "sweating" surface is formed on the surface of the first layer of Stellite instead of on the steel. This time the joining may be more of the nature of welding, because it is the joining up of two layers of the same material and a good bond is achieved by the complete intermixing of these two layers. Any slag and scale which has been brought to the top surface of the first layer must be floated forward and upward into the second layer, otherwise imperfect bonding will result. The finishing operation must also be carried out on this layer, while the cooling of the last portion also needs the special attention similar to that mentioned above. If the amount of Stellite deposited is now considered enough—too much is wasteful of costly material, while not enough means re-stelliting, with consequent loss of time, etc.—the component is transferred while still hot to a box containing Keiselguhr, lime, or any non-conducting material, and allowed to cool slowly. Quick cooling in air tends to form hair cracks in the Stellite, resulting in early failure of the component through erosion and flaking.

Treatment of Stellited Parts

If, after cooling, the parent metal needs heat-treatment, this can be done in the normal manner, but it is essential that any quenching out from low temperatures should be carried out in oil and not water. Heat-treatment does not affect Stellite, but the parent metal must always be put into a state of the best physical properties for the intended component. The nickel-chrome austenitic steels, after stelliting, are normalised from 900° C. This operation merely removes strains set up in the parent metal and has very little effect on the grain size after stelliting. This is

probably due to the sluggishness of these metals to structural alteration through heat-treatment, as normalising at 900° C. for several hours does not modify the crystal size to any great extent. One advantage of this normalising operation is that after thread-grinding the outer diameter of the component does not " spring " or distort as in the same material which has not been stellited or normalised.

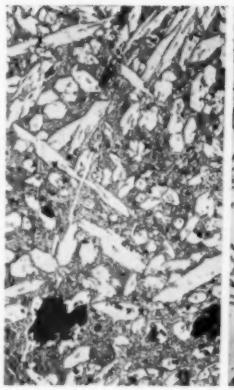


Fig. 7.—A type of defect which may result when the Stellite is kept at too high a temperature. ×56.

Fig. 8.—Similar defect as shown in Fig. 7 showing how blowholes are positioned. ×375.

Fig. 9.—The position of affected areas shown up on machining. ×56.

Fig. 10. — Inclusions which are revealed in machining operations. ×8.

After heat-treatment the components are then machined. Due to the relative softness of the Stellite used in these operations, this material can be rough-turned and then finally ground to finished size. Turning is carried out, using tipped tools of the tungsten-carbide type, at speeds of approximately 140 ft. per min.

An advantage of the turning operation is that it gives a rough indication of the quality of the stelliting, in that, due to the shape of the valve and valve seat the ring of stellite deposited should be truly circular, and any variation in ovality is due to " washing " or overheating.

Testing

Due to the high standard of quality required for aeronautical work, it is imperative that operators' work should be frequently checked, to ensure that this standard is being maintained. With the stelliting of exhaust valves and seats the method of examination usually results in the component being sectioned, thereby destroying it for future use. In repetition work, the frequency of the checks will depend on the output, but at the same time the checks must be often enough to ensure that the operators cannot fall into bad habits before the next test. Thus, if the standard of any one operator begins to fall, his faults are immediately found and can be rectified quickly. As stated before, microscopic examination is carried out periodically on valves and seats, and it is from this examination that the quality of work being produced can be assessed.

The sections are cut from the valves and valve seats by a thin elastic wheel, care being taken not to " blue " the component. These are then ground flat, either by hand or machine, the usual methods of filing, etc., being hopeless with this material. The well-known methods of polishing are then followed, finishing being done on a revolving pad moistened with water, and using diamantine or chromium-sesqui-oxide, as a polishing medium. In this condition major faults, such as blow-holes, etc., can be seen, but higher magnifications must be used if defects in the stellite or bond are to be found (Fig. 1).

Due to the corrosion resistance of Stellite, normal etching reagents do not attack it, but by using suitable solutions, either the base metal or the Stellite can be etched without staining or interference from the other.

To etch the austenitic base metal, 1·20 S.G. HNO_3 is suitable, but this does not etch the stellite, and a hot solution of 10 grms. pot. ferricyanide, 100 grms. water, 10 grms. NaOH is used. The specimen should be washed between these stages of etching, otherwise Prussian Blue is formed, which tends to stain.

Examinations are then carried out on the etched specimen, first at about 50 magnifications to get a general indication of the quality of the product, followed by the examination of such important places as the bond at magnifications of 200–500. If the components were sectioned diametrically, this will give a good indication of the quality of the work throughout. It is in this examination that defects due to overheating, working too cold or too quickly, burning, etc., are found, as each of these faults are shown up quite distinctly on the microsection. It should also be realised that the quality of the original Stellite rod has a great bearing on that of the finished component.

As the bond between the Stellite and the steel is of the greatest importance, the examination of this area is probably more stringent than that of any other parts.

As previously noted, if the Stellite is applied too cold impurities are found at the bond, sometimes accompanied by small blowholes.

Such an example is shown in Fig. 2, which clearly reveals the extremely poor joining between the steel and the stellite. The grain size of the steel is smaller than that of the seat having a good joint.

The effect of using a very high temperature in the depositing operation is shown in Fig. 3, which shows the massive grain size of the steel and also how the Stellite has eroded the original surface of the steel, thus allowing abnormal penetration of Stellite. This may actually have a very high bond strength, but the intermixing of the steel with the Stellite has lowered the corrosion resistance of the latter.

A good joint is that in Fig. 4, showing how the steel surface has just been hot enough to form a thin alloy film with the Stellite, yet not so hot as to cause excessive grain growth or severe intermixing of the two materials.

Slag in Stellite differs from oxide inclusions that it is usually in small globules which often have coagulated into unsound areas. These globules are very rarely found near the bond, and are caused by minute slag particles on the Stellite rod coagulating during the stelliting operation. Figs. 5 and 6 show to what extent these particles accumulate, the latter photograph showing the similarity of structure of this type of slag, with the type sometimes found in ferrous materials. As these inclusions do not follow the dendritic structure of the Stellite, it is highly probable that they have a melting point higher than that of the surrounding material. This would account for the formation of the " trailers." When the Stellite was at high temperatures, partial disintegration of these inclusions would result, and during the " whipping-up " of the Stellite in the finishing operation these finer portions would become detached from the main globule. In the cooling operation, these detached streamers probably act as nuclei for the formation of the fine vein—like hardeners of the stellite. Sometimes a new operator will keep the stellite at too high a temperature for lengthy periods and the metal

may become burnt. Such a structure is shown in Figs. 7 and 8, the former showing the general appearance of this type of defect and the latter showing how the blowholes are positioned in relation to the remainder of the structure. In this state, the metal is useless, but it often happens that only a small portion of the deposited stellite may be in this condition. However, the position of these areas are shown up on machining, by the very roughened or sponge-like surface they present (Fig. 9). Another defect sometimes found is that of the operator leaving scale and dirt at the top of the first layer, instead of remelting and floating these inclusions to the top of the second layer, where they would be removed by subsequent operations. Again, this defect is revealed in the machining operations, because where these inclusions occur that portion of the surface will " smear " or even tear out. A small area of torn metal is shown in Fig. 10.

Conclusions

Due to the arduous conditions prevailing in the combustion chamber of modern high-efficiency aero engines, it is mainly by the application of modern materials that the poppet-valve engines have been given a new lease of life.

The fact that stellited valves and seats are now able to operate under the above conditions for considerable periods proves that applications of materials developed by scientific research may overcome otherwise unsurmountable difficulties.

It has been the experience of the author that provided the stelliters work in harmonious co-operation with the laboratory, then it is possible for stellited production work to be of an extremely high grade ; while the absence of faults and defects from valves and seats has undoubtedly aided the increased power outputs characteristic of the modern poppet-valve aero engines.

British Chemical Standards

At the recent technical meeting of this reorganised company, a Report covering the seventh period of working was presented, and the results indicate that it has won the approval and support of chemists, as will be noted in this abridgement of the Report.

A NOTEWORTHY achievement is indicated by the Report of British Chemical Standards covering the period from September, 1935, to November, 1938, during which reorganisation was effected, as is shown by the new samples issued in that period ; also, the number of standardised elements :—

New B.C.S. issued during the period.	Number of elements standardised.
Austenitic iron " L "	8
Low carbon ferro-chromium, No. 203	3
High carbon ferro-chromium, No. 204	3
Ferro-vanadium, No. 205	1
0·5% carbon steel " F "	5
Rapid-machining steel " D " (high S. and P)	5
Hæmatite iron " A 3 " (renewal of hæmatite iron " A ")	8
Nickel-chrome-molybdenum steel " B "	8

Total number of British Chemical Standard samples now available is 41. Total number of British Chemical Standard pure reagents and metals is eight.

New British Chemical Standards in course of preparation or standardisation are :

2/10/88 bronze " C," No. 207.
3% Si, 1·5% P iron, No. 206.

In addition to the above, we have increased the number of analysed samples for students, which are prepared mainly for colleges and other training institutions. The new samples include :

41 G zinc concentrates.
42 G lead concentrates.
43 G tin concentrates.
44 G iron pyrites.
45 G copper-lead matte.
47 G copper-nickel speiss.

The complete record of analysed samples of various kinds, now available, comprise 14 carbon steels, five alloy steels, six cast irons, one slag, two ores, seven non-ferrous alloys, six ferro alloys, and eight pure standardised reagents and metals, in addition to 45 analysed samples for students. During the period under review the weight of standard samples sold was 404,629 g (95·9%), against 292,725 g (94·2%) during the preceding three-year period, showing a 25% increase since the new company was formed.

Prices have remained unchanged in spite of a definite increase in price of general commodities. This indicates that the new company, organised on a more efficient and self-perpetuating basis, has won the approval and support of chemists, generally, and thereby become more firmly established. At the same time, the company has proved itself self-supporting financially ; a feature which is reassuring to those who wished to be assured of continued supplies.

From tabulated figures showing the relative demand for each standard, the greatest call is still for plain carbon steels and cast irons ; after which come alloy irons and steels, then non-ferrous alloys, and finally, ferro-alloys. Non-ferrous chemists will find it profitable to make fuller use of the standards available to them and ferrous chemists could usefully take advantage of the increased number of ferro-alloys which are now available. The demand for the new Ni-Cr-Mo steel " B," also the high sulphur and phosphorus rapid-machining steel " D " is encouraging, especially as each of these steels has been issued for less than a year. It is noteworthy that the pure reagents and metals for analytical standardisation, pyrometric work, etc., are becoming better known and used ; for instance, the demand for benzoic acid as a means of standardising alkali solutions is now considerable.

Future Work

The greatest demand is still for carbon steels and irons, and any gaps in the series will be filled as far as possible.

The series of non-ferrous standards is far from complete, but unless the demand for these increases there will not be much encouragement to complete the series.

The interest in quantitative spectrographic analyses is being watched, and the possible need for standard samples in lump for this purpose will receive consideration.

New samples for students will be needed from time to time, and will be prepared in due course.

The company has been approached with regard to supplying standard sands for checking mechanical sieving tests and testing artificial bonds used for foundry work ; but this presents certain difficulties, and no decision has been come to, as yet.

Suggestions for future work, we are informed, are welcomed from all sources, and will receive adequate consideration.

Industrial Management and Production Control

Part VI. (*Continued*)—The Time Study Man and His Task

By F. L. Meyenberg

The article shows how the work of the time study man has changed since the days of Fred W. Taylor, how it has developed into research work on all problems related to the working of machines and the labour of men, and which qualities are therefore expected from the man who has to do this job. Further, it points out that important work which still lies before him—i.e., the classification and evaluation of work with all methods, which not only technical science, but also current physiological and psychological knowledge, will, it is to be hoped, develop in future.

Stating the Problem

The problem is to evaluate in a fair manner the difficulties of different types and kinds of work on the one hand, of the capacity of human beings on the other hand, and to bring both together in such relations—i.e., measuring them in such a manner that payment in money can be determined on a fair and equal basis for the work done, according to its immanent difficulties and the available human capacity.

The Classification of the Work

We have seen that "time" is necessary in evaluating performance, but that it is not sufficient. That does not mean that the importance of the determination of time should be considered as of less significance than at present, but that some other things have to be taken into account besides time. We recognise at once how correct this aspect is in considering the different evaluation of the period of time, say, an hour, when the workman is doing different jobs—one pleasant, the other unpleasant to him. That shows that the value of a performance is dependent not only on the time used, but on the man exerting certain qualities, such as thought, attention, physical effort, intelligent anticipation, fatigue resistance, etc.

If the workman is to feel that the payment is fair, not only the *result* of the work, which is measurable by quantity, weight, time, etc., but also the *expenditure* of work the performance, which is not measurable by one of our usual measuring systems, must be taken into account in some other way.

As some measure—or should we say, some kind of estimation—has to be found for the latter, a classification of the work is necessary according to the difficulty of performance. The question arises whether this should be done from the point of view of the work or from that of the man. The answer is that preference should be given to the first point of view as being more objective, but where necessary, perhaps because a criterion of the first kind is missing or for any other reason, then the second point of view should also be considered. Thus we have to distinguish the classification :—

1. According to the difficulty of the work—i.e., the demanded or expected efforts of the workmen, which may be of physical, mental, or psychic nature.

2. According to the efficiency of the workmen. Here again a partition may be possible :

(*a*) In so far as the efficiency of the man can be judged by comparing his actual efforts with what could be performed by a presumed and continually practicable effort, which we may consider as an average performance.

(*b*) In so far as the efficiency of the man depends on personal qualities, as his being qualified for or trained in the special job ; his knowledge, dexterity and experience, his trustworthiness, accurateness, and his readiness to take responsibility, etc.

1. Classification According to the Difficulty of the Work.

Let us consider somewhat more in detail the classification under (1), which is, as already mentioned, that which should have preference as far as possible. A non-exhaustive survey with some examples may perhaps show what properties may be decisive in classifying the work according to its demands on the men :—

(A) *Demands on Physical Qualities and Movements.*

(*a*) Heavy muscular exertions repeated, but only momentary maximum performance (e.g., transport work, furnace work), or as continuous work (forging, despatching). Handling heavy work-pieces (constructional work). Trying attitude during the work (miner, former). Shocks on pressed-air tools.

(*b*) Quick and handy movements (shunter), strained skill (assembly on a moving belt), dexterity and courage, being free from giddiness (painter on constructional work, assembly of bridges, chimney sweeper). Quick motions at work without considerable muscular exertion (weaver, precision-worker in mass-production, as wireless sets, telephones, etc.). Quick reaction (crane-driver, motor-driver).

(*c*) Special influences from outside, as : Work in open air in all weather, radiant heat (furnace-worker), with abrupt change of temperature (foundry, iron and steel works), or high temperature in closed rooms, sometimes with high degree of humidity (firemen in ships, chemical industry, laundries, production of leather-ware). Work in narrow rooms with limited air (boiler-cleaning). Influence of dust, smoke, gases, steam ; necessity of wearing protective clothes, goggles, respirators. Special circumstances of atmosphere (work in caissons, in mines, on high mountains, in dark rooms, including work of special danger (constructional work, quarries, some work in shipyards).

(B) *Demands on Qualities of the Senses and Common Strain of the Organism.*

(*a*) Strain of the eye in handling very small parts, perhaps difficult to distinguish (textile industry, printing-offices, factories of fine-mechanics), especially if the lighting is not first class (photography). Strained listening (wireless operator, worker testing motors). Strain induced by dazzling (furnace-worker, motor-driver at night), noise (weaving-mills, boiler-smithy), shocks, especially of the ground (motor-driver).

(*b*) Resistance against fatigue and slackening of attention —for example, when testing, inspecting or supervising, or when carrying out one of the above-mentioned activities continuously ; night-work, overtime, monotonous work, which cannot be mechanised (e.g., punching of Hollerrith cards, work on sensitive measuring instruments). Inconvenient attitude of the body as rule. Lengthy seeking and testing (e.g., seeking of defects in plants, in statements of figures, controlling measures in drawings). Continuous observation of surroundings, besides the proper production activity, strained caution (mines, work in high-frequency plants, handling of poison and explosives).

(*c*) Resistance against obnoxious symptoms of the work (wetness, noise, heat, smell). Overcoming of indecision and physical anxiety in dangerous situations (overhead and underground workings, mining, electrical engineering, test-house, laboratory).

(C) *Demands on Spirit and Character.*

(*a*) The work requires special carefulness, caution, or accuracy, as, for instance, checking measures, quality of surface; economical utilisation of material; observing delivery dates. Working highly valuable or dangerous material. Work of the staff with figures in book-keeping, with ready money. Mostly inspecting and testing.

(*b*) The work requires assumption of responsibility for the result—i.e., answering for quality, accuracy, safety (inspecting, individual handiwork, welding).

(*c*) The work requires especially professional knowledge and experience.

(*d*) Proper meditation on the work, or calls for initiative (for example, resourcefulness when technical problems arise, or when mistakes must be found. Organisation and preparation; survey of the relation between the various parts of work, apart from the actual present operation). Work on new material or plant. Responsible work outside the works (projection, assembly). In a word, the work is far from "routine" work: new problems must be solved.

(*e*) The work requires self-assertion with subordinates or customers; influencing other people, as educator or propagandist: explaining, instructing, training, leading, representing the works internally and externally. Negotiating with responsible decisions (purchasing, intercourse with the public and governmental departments, superintendence, also of small groups of men, training of apprentices).

2A. Classification According to the Efficiency of the Workman Generally.

In contrast to the attempt under (1), to find out *final* figures for the evaluation of the work according to the various qualities necessary to overcome the difficulties in each type of work, we have now to look for a measure of the *variability* of the values which we are seeking as the result of the expenditure of workman's performance. It is the well-known "degree of efficiency," regarded as so important in all systems of incentive wages, which we now attempt to determine. But in doing that we cannot take as guide the *result* of the work, expressed in quantity or time, because this may be greatly influenced by factors outside the sphere of the man—already taken into account under (1)—we can only rely on observation of the process itself, as it is performed, or should be performed, by the man. We must therefore take into account his avoidance of defects and rejects, his observation of time and quality demands, his economy in the use of materials, his correct use of machines and tools, etc. Our aim is to find out an "average" performance, with which the actual performance in a special case can be compared, but this average performance "purified" from all influences which the work itself may involve, as these are already considered under (1).

2B. Classification According to the Quality of the Individual Worker.

While the point of view discussed under (2A) intentionally refrains from the personality of the observed workman—we do not know beforehand how to evaluate his qualities, and are looking only for the average performance—we have now to estimate the individual performance before us, how far it is based on his qualification for the work in question, on his training, on his knowledge, experience and skill; on qualities of character, as carefulness, initiative, worthiness of confidence, etc.

Evaluation of the Work

When the characteristics of the various kinds of work have been determined by such analysis, the second and equally difficult step could be taken—to establish the various kinds of work according to their value as ascertained by means of measures, which must be adapted to the individual qualities of the work in question. As far as permissible, we will, of course, choose *time* and *quantity of output* as measure, but a glance at our enumeration of characteristics shows that that is possible only to a limited extent; at the moment, however, when we come to such a limit, a difficulty arises which may be founded on the kind of training of the majority of persons which have to tackle these problems: the scientist and engineer are accustomed to think in facts and figures, and may hesitate when they have to enter a sphere of speculation and instinctive feeling, but have to adopt this way of thinking, at least so long as physiology and psychology do not provide a basis of measurement. He must use his *gift of observation*, and after careful description of what he has seen, attempt to estimate the work observed according to the difficulty it causes during performance. In order to achieve more impartial judgment, this experiment should be made simultaneously, but independently, by several persons, and the results equalised in sincere co-operation.

Sometimes *estimation based on comparison and experience* is the best way, but can be chosen only if the two performances which shall be compared have so much similarity that a comparison is really permissible. It is certainly wrong if operations in one trade or in one industry are put on a par with operations of similar type in another trade, where different working conditions, other surroundings, etc. influence the workman.

Finally, even an evaluation according to *common sense* or *agreement with the workman* may be possible in cases, where other means are not at hand. It must be admitted that this cannot be regarded as "measures" any longer, and this method should be limited to cases where another way is either impossible or not worth while owing to the temporary nature of the work.

Classification and Evaluation in Practice

Surveying all these considerations of how to classify and evaluate work, I am well aware that many people in practical life will doubt the usefulness for actual application, and, shrugging their shoulders, dismiss the matter as "a theoretical whim." They should not behave with so much superiority. On the one hand, it would not be the first time that such an idea, ridiculed in the beginning, but sound in principle, gives an impetus to a valuable development; on the other hand, I can assure my readers that the practice already attempts in many cases—but, it may be admitted, more or less haphazardly—to overcome the difficulties which arise from present working conditions.

Of course, in order to be successful in these endeavours, three suppositions must be fulfilled: First, accurate results of sufficiently comprehensive work and time studies must be at hand; secondly, the confidence of the workmen must have been obtained that no "price-cutting" of any kind will take place; and thirdly, that existing agreements either give sufficient free play for introducing such a classification without endangering the economy of the works, or can be altered correspondingly. Further, all concerned must be aware of the fact that this is a job that needs time, patience, and good will, that only real co-operation can lead to success, that—particularly in the beginning—mistakes are natural and should be corrected by mutual consent; but just these difficulties—or, rather, their overcoming—bear in themselves a reward in so far as they offer numerous occasions to create that right spirit in the works, contributing to that appeasement of the relations between management and men which must be considered as the necessary condition for continuous success.

Logically, our considerations will lead to tables or graphs containing figures of evaluation which represent the results of all investigations; and there will be several of these tables, each indicating another method of measuring and judging as enumerated above, and they must be

combined in the correct manner for a special job. They must also be adapted to the peculiar working conditions of the shops where they are developed, and they cannot be transferred from one shop to the other, even less from one works to another. It may be that development will finally lead to such a possibility, but at present we are far from this goal. There again lies a great danger: that the work we are discussing degenerates into routine work, that these tables of evaluation are used by persons who do not understand what is behind the figures and apply them in a wrong manner. They should be only in the hands of men like the time-study man, as we have described him in the first part of this article—a research engineer, whose investigations are not concerned with the working of a plant as a mechanism or with the quality of material, but the economical production of goods with special regard for labour conditions; perhaps we may characterise him as a "production research engineer?"

The Mechanism of the Reaction Between Hydrogen and Carbon in Iron

AN investigation, made of the theoretical principles underlying the reaction between hydrogen and carbon in iron, is described by Walter Banklop and Bernhard Knapp, in *Carnegie Scholarship Memoirs*, Vol. XXVII, recently published by the Iron and Steel Institute, which provides an important contribution to the mechanism of reaction between hydrogen and carbon in iron in the solid phase.

The chemical basis of the reaction between the hydrogen and the carbon in the iron is that indicated by the following equation:

$$Fe_3C + 2H_2 \rightleftharpoons 3Fe + CH_4.$$

The Fe_3C does not occur in the free state, but is distributed in greater or smaller proportion as a structural constituent of the iron. Thus, in the first instance, the reaction between hydrogen and the carbon takes place directly on the surface of the steel, but the iron produced renders further access of the hydrogen to the carbon more difficult, as the former must diffuse through the iron before it can react with the carbon. As long as this diffusion is taking place more slowly than the reaction itself, it governs the speed of the reaction, which thus becomes dependent on the temperature, carbon content and hydrogen pressure—the three factors governing the process of diffusion. Above the line GOSK a fourth factor also operates, namely, the methane equilibrium diagram in accordance with the above equation.

From above 850° C. upwards the rate of the diffusion of carbon is greater than that of the reaction between the hydrogen and the carbon; hence the slower process is the reaction itself, and this takes place in accordance with the conditions of equilibrium. The scope of the theoretical investigation was made to cover the question of the formation of the sharply defined boundary zones free from carbon. These are of three kinds, distinguished by their chemical composition as follows:

1. Pure ferrite boundary layers existing below the GOSK line.
2. Transition boundary layers in which the carbon content diminishes outwards. These exist between the GOSK line and approximately 850° C.
3. Hypereutectoid boundary layers with a carbon content corresponding to the line ES. These exist above 850° C., within the two-phase region—austenite plus cementite.

To elucidate this phenomenon reference is made to the equilibrium conditions of the iron-carbon-hydrogen system, and, in the third case, to the high rate of diffusion of carbon in iron. In order to represent in practice the unavoidable loss of methane from the reaction zone, a sort of "whirling action" is assumed.

An account is given of the practical results obtained from the author's experiments. Two series of experiments were carried out, the first being to determine the total amount of decarburisation undergone by turnings placed in a stream of hydrogen, and the second to determine the formation of boundary layers in cubes placed in a hydrogen stream under high pressure. The results from these experiments showed good agreements with the theoretical results.

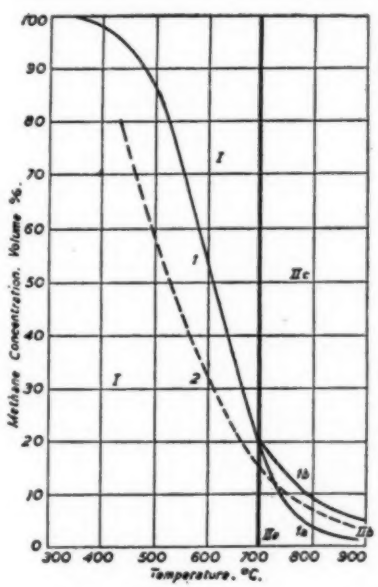


Fig 1—Equilibria in the iron-carbon hydrogen system.

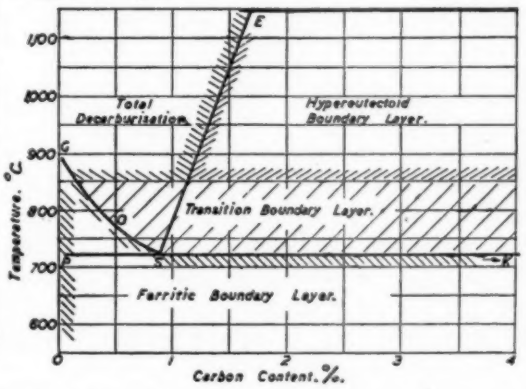


Fig 3—Relationship between the iron-carbon diagram and the formation of boundary layers.

Fig. 1 represents the following equilibria at one atmosphere pressure:

Curve 1: $3Fe + CH_4 \rightleftharpoons Fe_3C + 2H_2$.

Curve 1*a*: Decomposition of CH_4 on ferrite plus low-carbon γ solid solution.

Curve 1*b*: Decomposition of CH_4 on cementite plus high-carbon γ solid solution.

Curve 2: $CH_4 \rightleftharpoons C + 2H_2$.

For convenience the diagram is divided by a vertical line through 695°C. into two fields, namely, field I. from 300° to 695°C. and field II. from 695° to 900°C. Field II. is further divided into three sections by the two branches 1*a* and 1*b* of the curve, and these sections are designated II*a*, II*b* and IIc, respectively.

Vickers Limited announce that the Rt. Hon. Lord Hailey, G.C.S.I., G.C.M.G., G.C.I.E., has been appointed a director of the company.

The Influence of Some Special Additions on Certain Properties of Cast Iron

Results of investigations on the influence of some special elements on the graphitisation of cast irons are briefly discussed, including cobalt, titanium, boron and cerium.

THE influence of some special elements on the graphitisation of cast irons during solidification, and on annealing has been studied in a series of researches described by P. G. Pastien and L. Guillet, junior.[1] Utilising the specimens prepared for these tests, the authors have also determined the physical and mechanical properties of these special cast irons, as well as their resistance to corrosion. The elements, the effects of which have been investigated, are cobalt, titanium, boron and cerium. As far as possible, the method adopted for the study of these various special cast irons was the same for all elements investigated. Except in the case of boron, two series of cast irons were prepared for each added element; for the first series a total carbon plus silicon content of the order of 5% was aimed at, whilst in the second series the total content of these elements was intended to be about 4%.

In each series the percentages of added elements aimed at were 0%, 0·05%, 0·1%, 0·2%, 0·5%, 1%, 2% and 5%. For each set of melts, the authors studied, in particular, the influence of the percentage of added element on the chilling properties, the micro-structure, the graphitisation, and growth due to annealing, the temperature of the Curie point of the cementite, the resistance to corrosion in a dilute solution of nitric acid, and the mechanical properties.

The mechanical properties were mainly concerned with hardness, Young's modulus, and shearing and transverse strength tests. The conclusions arising out of these experiments and tests are given as follows:

Influence of Cobalt

Cobalt added to cast iron has a slight graphitising effect. It promotes graphitisation of the melt during solidification, as is proved by variations in the depth of chill and the quantity of graphitic carbon, and also graphitisation on annealing, by lowering the temperature of incipient graphitisation. From equal quantities of graphitic carbon, it refines the graphite; but when it is present in sufficient quantity, it affects the distribution of the graphite, which becomes heterogeneous.

It is very largely dissolved in ferrite, according to the iron-cobalt-cementite diagram of Vogel and Sandermann, and slightly increases the electrical resistivity, the thermo-electro-motive force and the resistance to corrosion in dilute acids. It also appears to go into solution in cementite to a certain extent, as is indicated by a rise in the Curie point of the cementite.

It diminishes all the mechanical properties studied (hardness, modulus of elasticity, transverse and shear strength, and deflection at rupture), rapidly at first, then slowly with increasing quantities added, although it is impossible to account for this behaviour merely by the increase in the quantity of graphitic carbon.

Influence of Titanium

In agreement with the results of previous investigators, titanium is a graphitiser, the effect of which is definitely pronounced during solidification. When titanium cast iron is annealed, the graphitising effect of the added titanium, in the percentage limits studied by the authors, does not influence the temperature of incipient graphitisation, which is roughly constant. On the other hand, the addition of titanium increases the linear growth of cast irons. This element has a marked effect on the size and distribution of the graphite segregated when the melts solidify. This effect may be manifested in two ways: (1) by a general refining of the graphite lamellæ, and by the formation of two types of graphite, which differ considerably as regards size. Titanium also refines the temper carbon.

In the range of compositions studied by the authors, titanium appears to have practically no effect on the temperature of the cementite anomally, A_0, which tends to show that it does not go into solid solution in Fe_3C. In cast irons it is present either in solid solution in the ferrite, as is shown by the equilibrium diagram Fe-Fe_3C-Fe_3Ti, or else is combined in the form of the carbide, TiC, or complex compounds (TiC-TiN).

As regards the hardness and mechanical properties, the overall effect of titanium is the resultant of two actions: It favours graphitisation and consequently tends to lower the strength properties, but, on the other hand, it goes into solid solution in the ferrite, and structurally refines the graphite, with a consequent tendency to raise the strength properties. Curves with minima are given for the hardness, modulus of elasticity, shear strength and transverse strength, these minima being particularly marked for cast irons having low or medium percentages of total carbon and silicon. Beyond these minima, the addition of titanium again raises the strength properties of cast irons, but this increase is not sufficient, with cast irons having average or low percentages of total carbon and silicon, to compensate for the decrease due to the graphitising action of titanium.

Influence of Boron

Boron inhibits the graphitisation of cast irons when they are solidifying, and acts as an energetic whitener of the structure. It similarly opposes graphitisation during annealing, by slowing down the speed of decomposition of the cementite, but it does not appear to affect the temperature of incipient graphitisation, at least in the range of boron contents studied by the authors.

Boron uniformly and rapidly raises the temperature of the cementite anomaly, A_0, a result which confirms the existence of the complex cementite (Fe_3C—Fe_2B) postulated by Vogel and Tammann in their equilibrium diagram of the Fe-Fe_3C-Fe_2B alloys. This element raises the mechanical properties (hardness, transverse strength and sheer strength) of grey cast irons, but, on the other hand, reduces their capacity for deformation (deflection).

Influence of Cerium

The influence of cerium[2] depends essentially on the method of making the melt to which it is added, and the way the addition is made. The investigations show that the remarkable whitening power of this element may be concealed under certain conditions of treating the melt involving a slag containing a high percentage of oxide of iron. The results agree with those obtained by Schwartz and Guiler, who showed that even a very small percentage of added cerium prevents graphitisation.

[1] Carnegie Scholarship Memories, Vol. XXVII, pp. 77-143.

[2] An alloy containing 51·27% cerium, 47·71% rare metals (particularly lanthanum), and 1·02% iron, and known as "Mischmetall," was used to supply the cerium.

Metal-Sprayed Bearings for High-Speed Operations

The results of tests on sprayed-metal bearings, in comparison with cast bearings, given in a recent paper by Mr. Harry Shaw to the Association of Metal Sprayers at Birmingham, show the effectiveness of sprayed-metal bearings. Some of the results, as discussed by the author, are given in this article.

TESTS have been carried out with spraying metal bearings at speeds ranging up to 3,000 ft. per min., and with loads up to 8,000 lb. per sq. in., corresponding to the speeds and pressures encountered in modern high-speed internal-combustion engines. The tests were made on a battery of eight Shaw wear- and friction-testing machines, which enabled eight tests to be carried out at the same time.

A wide range of bearing metals built up by metal spraying were obtained for test-pieces; these samples were obtained from actual production work, so that specimens did not consist only of bearing metals sprayed specially for tests. Specimens included sprayed metals from France, Germany and America, and it is noteworthy that, without knowing anything of the local conditions under which the spraying was done, the work tested from these countries, with the exception of that from France, differed from British work. Sprayed-metal specimens from America generally showed a higher tensile strength, but the bond of adhesion is between 20% and 50% weaker than similar British work. The Americans favour very coarse machining and the cutting of checker patterns in the work surface to form a bond, and this is often done without regard to its weakening effect on the piece. American work checked has been found very poor under impulse loading, due, apparently to this poor bonding.

German spraying is similar to British, but there would appear to be great difficulty in obtaining other than standard alloys in wire form. Great attention is paid to the preparation of the surface; very fine machining is favoured for the bond and finer feeds and cuts are used than in British work, but, in the preparation, Germans appear to use the tool in such a way that a spikier finish is obtained in the direction of the cut than in this country.

TABLE I.

Bearing Alloy.	Composition.							
	Tin.	Cadmium.	Copper.	Lead.	Antimony.	Zinc.	Silver.	Other elements.
Babbitt No. 1	89·97	—	2·53	0·173	7·32	—	—	—
Babbitt No. 2, CR.	90·16	—	2·61	—	7·15	—	—	—
Babbitt No. 3	89	—	4	—	7	—	—	—
Babbitt No. 4	88	—	3	—	3	—	—	—
Cadmium-Silver-Copper. CR. ..	—	98·91	0·46	—	—	—	0·015	0·510 Ni
Bronze No. 1	0·75	—	60	—	—	39·25	—	— 0·03 Ni
Bronze No. 2	1	—	58	—	—	40	—	0·85 Fe 0·03 Mn.
Lead Bronze CR.	5	—	80	15	—	—	—	—

By far the widest range of alloys can be obtained in Britain in wire form. The analysis of different alloys which have been found satisfactory for spraying for bearing applications are given in Table 1. A good babbitt for metal spraying is one containing about 9% antimony, and the strength of this alloy can be improved by annealing for about 48 hours at 100° C. where this is possible.

Tests on Babbitt

A comparison between the curves for cast and sprayed babbitt shows that the sprayed babbitt has a coefficient of friction lower by about 25% than the cast babbitt at a speed of 1,000 ft. per min., and that the seizure load has increased from 7,040 lb. to 7,560 lb. per sq. in. At a speed of 3,000 ft. per min. the seizure load is 3,840 lb. for the cast babbitt, and 5,120 lb. for the sprayed babbitt. Before the seizure load is reached on the cast babbitt a point of instability of friction is reached at which the friction fluctuates. This condition of fluctuation never occurs with the sprayed metals, due to the porosity supplied by actual reservoir action, and by seepage effects from surface heat, sufficient lubricant preserves the greasy or boundary condition. All the tests with colloidal graphite showed almost complete absence of this fluctuating action, except in one or two cases immediately before seizure, due to the lubricating value of the graphoid surface at high temperature in preventing pick-up. The most remarkable reduction in friction is shown for the 50-ft.-per-min. speed where the sprayed metal has a friction at least 25% less than that of cast babbitt.

Lead Bronze

When new, sprayed lead bronze has better anti-frictional properties than cast lead bronze at all speeds. After thorough running-in the friction rises slightly, and that of the cast lead bronze drops until the curves for the two run practically together. Examination of the surfaces, both under the microscope and with the Shaw Contorograph, revealed a perfectly smooth surface free from pits or porosity due to the flow of a lava of lead on the surface. It was found, however, that the seizure load of the sprayed lead bronze at the high speeds is higher by about 20% than that of the cast lead bronze. When the surfaces of bearings of the sprayed lead bronze were examined after running for a very short time near to the seizure point, it was found that very minute pores had opened up in the surface. Round each pore was a little mound of metal with a jagged edge, just as though the skin of lead had been burst by gas pressure from beneath the surface. Continued running spread out these mounds of lead until they were flat again, the pores still remaining until covered up by further spreading of the lead. Immediately pre-seizure conditions were returned to fresh pores were formed in the same way. The seizure load of the lead bronze tested, one of typical analysis, is inferior to that of the babbit tested. Whether this would apply with lead bronze of other analysis is not known at this stage.

Cadmium-Silver-Copper Bearings

Other materials such as cadmium-nickel, cadmium-nickel-silver and cadmium-silver-copper have been developed with the object of producing a metal free from cracking. Generally, these materials have a higher coefficient of friction than the tin-base bearing metals. A cadmium-silver-copper tested had a higher seizure load than the lead bronze, 5,120 lb. at 3,000 ft., as compared with 4,160 lb. for the lead bronze, while at the 1,000-ft. speed its seizure load was 6,080 lb. against 4,250 lb. for the lead bronze. Also the cadmium-silver-copper had a lower friction than the lead bronze. A sprayed cadmium-silver-copper of the same analysis had a lower friction than the cast metal, and a higher seizure load, and had no point of fluctuating friction.

New Pitted Bearing Tin Coated

With the object of developing a bearing that would have the non-cracking properties of a lead-bronze or a cadmium-nickel or other such bearing, together with the good anti-

frictional properties of a tin-base metal and the safety factor of such a metal, tests have been carried out on a new type of bearing in which a metal of high tensile strength and/or high heat conductivity is covered with fine pores or pits of a size such as, say, five-thousandths deep by five-thousandths in diameter, into which tin or a tin-base metal is loaded by any convenient means. The tin-base metal cannot crack, because it is held in the very fine pores or pits of the backing metal, say, copper. In running, the load is taken by the tin-base metal, so that the friction is that of a tin-base metal aided by the peculiar channel effect created between the tin-filled pores and the copper backing, the tin remaining in relief above the backing.

Tests made on a bearing made with a pitted copper backing filled with tin by the metal-spraying process show that this bearing has a friction that is but a fraction of that of either the lead-bronze or the cadmium-silver-copper. At the high speeds it is but a third or a quarter of that of these metals. It was not found possible to get seizure at loads below 8,000 lb. per sq. in. with the 1,000-ft. and 3,000-ft. speeds. At the 1,000-ft. speed seizure did not take place at the 10,000 lb. load, the limit of the machine. As mentioned, the oil-channel effect between the tin-filled pores and the copper combined with the porosity of the sprayed tin, aid in preserving an oil film even at these high loads. Important developments in this type of bearing are expected.

Cracking under Impulse Loading

Comparative tests were carried out under impulse loads, the load being applied and released once per revolution at speeds of 2,000 revs. per min., and in no case did the sprayed babbitt or sprayed lead-bronze or cadmium-silver-copper of the analysis indicated by the prefix CR. in Table I fail from fatigue in any shorter time than the cast metals. The other metals have not been tested out for cracking. The nature of the cracking test was not such as to enable other than comparison to be made between a cast and a sprayed metal running in the one machine at the same time under the same conditions, and one test could not be related to another so that the value of the different metals from a fatigue cracking point of view could not be assessed.

Influence of Colloidal Graphite

Some of the tests were duplicated using a 0·2% addition of colloidal graphite to the oil. Its effect generally is to reduce the coefficient of friction, and to raise the seizure load. In tests at a speed of 1,000 ft. per min. the seizure load of the cast babbitt was raised from 5,760 lb. to 7,000 lb., while the seizure load of the sprayed babbitt was raised from 7,040 lb. to 7,520 lb. The seizure load of cast cadmium-silver-copper was raised from 6,080 lb. to 7,040 lb., while the seizure load of the sprayed form was raised from 6,720 lb. to 7,250 lb. The action of the colloidal graphite on the friction is most pronounced at the higher loading conditions.

Sprayed Aluminium Bearings

Tests in hand on sprayed aluminium as a bearing metal are providing interesting results. One or two aluminium alloys that were found of little use as bearing metals in the cast form were found good in the sprayed form. A range of metals of low friction are those containing 40% to 90% aluminium, 3% to 4% copper, 5% to 50% tin, 20% of a metal such as lead soluble in the tin, and 5% to 30% of a metal which does not form a solid solution with the basic mass, but which separates with the aluminium as a chemical combination, and which is harder than the basic mass (of such metal antimony or nickel can be used). Certain alloys such as aluminium containing 20% lead to form a bearing on the lines of a lead-bronze bearing, which are difficult to form by casting on account of the insolubility of the lead in the aluminium in the solid condition, can be produced with ease by metal spraying using two wires of the required metals.

Protection of Steel Against Corrosion

A MOST remarkable substance, especially from the point of view of protecting steel, is chlorinated rubber, which, when properly made, possesses extraordinary powers of resistance to the atmosphere, and to acids, alkalis, oxidising agents, and many other corrosive and solvent agents. Its discovery, early development, and modification for adaption to commercial use have all been the work of English chemists.

Chlorinated rubber, although mentioned in earlier patents, seems to have been first prepared in 1888 by Gladstone and Hibbert in connection with their researches on the chemical constitution of rubber. However, they made no investigation of its properties, which remained unknown till it was again prepared by the late S. J. Peachey, the well-known rubber chemist in 1915, who obtained it in the first instance by the action of sulphuryl chloride on rubber solutions. Later, Peachey used the principle of the direct action of chlorine gas on rubber in organic solvents, and he soon recognised the valuable properties of the material.

When first placed on the market chlorinated rubber, though extremely inert, suffered from the disadvantages that its solutions were very viscous and the film left by their evaporation was correspondingly irregular, thin, and weak. Consequently it was not till after the work of F. C. Dyche-Teague some years later, who invented a method for producing low viscosity chlorinated rubber, that any real commercial development could be made. As a result of this advance a small plant was started in 1931 at Walthamstow by Detel Products, Ltd., to develop the commercial possibilities, and in 1934 this company, of which Dyche-Teague is the technical director, transferred its activities to the present new works at Greenford, Middlesex.

Essentially, Detel is chlorinated rubber made in a special manner, involving the pre-treatment of the rubber, by which is produced a product of such a non-viscous character that if necessary up to 50% can be dissolved in a solvent, forming a brushable solution. It should be emphasised that the product is an entirely British invention, and is the original variety of chlorinated rubber to be made into a commercial proposition.

Application is by means of a brush or spray, as already indicated, like paint, and dries in about 2 hours or less, merely by evaporation of the solvent, leaving a tough, strongly adherent, non-poisonous, non-inflammable film. Amongst the surfaces, non-porous or porous, to which the material can be applied are iron, steel, or any other metal, including galvanised iron, wood, stone, artificial stone, plaster, concrete, asbestos, asbestos-cement products, paper, leather and fabrics, many of which are extremely difficult for paint. It is almost completely resistant to an extraordinary number of substances, including nearly all acids, inorganic or organic, concentrated or dilute, such as, for example, sulphuric, hydrochloric, nitric, mixed acid, acetic, chromic, and even hydrofluoric, as well as carbon dioxide and atmospheric corrosion. For iron and steel and other metal surfaces also a special variety known as "D.M.U." (Detel Metal Undercoat) is available, which contains other ingredients, so that the film has a very high proportion of finely divided metallic zinc, resulting in true anodic resistance to corrosion being given in addition, of particular importance for protecting steel against both the atmosphere and sea-water. Similarly, it is resistant to every known alkali in concentrated or dilute solution, such as caustic soda, caustic potash, ammonia, and ammonium salts.

Amongst a large number of other corrosive and reactive substances that have no effect are oxygen, ozone, chlorine, bromine, iodine, potassium cyanide, petrol, benzole, and all tar fractions, alcohol, and methylated spirits. The film also is not affected by a dry heat up to about 200° F., and a wet (water saturated) heat up to 100° F., and is an electrical insulator of high quality.

Strength of Marine Engine Shafting

The strength of marine engine shafting is considered, based on experience and the result of thorough investigation into causes of failure. On the basis of such experience the strength of shafting for this purpose may be more closely estimated. The subject is fully dealt with in a recent paper, extracts from which are given here.

THE strength of marine-engine shafting based upon experience and the results of thorough investigation into the causes of failure are discussed in a recent paper by Dr. S. F. Dorey, before the North-East Coast Institution of Engineers and Shipbuilders. It is considered that on the basis of such experience the strength of marine-engine shafting may now be more closely estimated than by making theoretical assumptions, such as have generally been done in the past.

Factors which have contributed to failures of crankshafts include those due to additional loading due to torsional oscillation, mal-alignment due to excessive wear-down of bearings, and axial vibration of crankshaft; also to defective forgings and bad shrink fits, while, in addition, it has been found that shafting is subjected to fatigue loading in rough weather. All these factors are discussed at some length, and a method of measuring rough-weather stresses on shafting is described, and some results obtained are given. But, since the engineer is rather apt, when encountering breakdowns, to consider at the outset that the material must be at fault, this essential matter is considered first.

Shafting Material

Shaft forgings are almost entirely made of mild steel having a tensile strength of 28–32 tons per sq. in., and in consequence, the remarks made in this section are practically confined to this class of steel. It might be claimed that, with its almost universal adoption for marine work and the extensive experience gained of its behaviour in service, little criticism can arise regarding the suitability of mild steel. Reference to a paper read by the author in 1935 to the Institute of Marine Engineers will show, however, that unless certain precautions are taken in the manufacture and design of large forgings their reliability and durability can be appreciably reduced.

Emphasis is brought to bear on the fact that the natural tendency towards the occurrence of any of the more common defects in steel forgings increases directly in proportion with the increase in size of the ingot necessary to produce the forging. The effect of mass is also important in the forging operation since, while in the smaller sections it is comparatively easy to obtain a satisfactory structure by mechanical work followed by a simple heat-treatment, with increasing size a much coarser structure is to be expected owing to the lower rate of cooling, and this, in turn is reflected in lessened physical properties.

That steelmakers are alive to the problem is evidenced by improvements which have been made in heat-treatment procedure, so that it is now a rule to give a double heat-treatment to important mild-steel forgings of large size, the first treatment, after rough machining, consisting of a normalising treatment followed by a fairly rapid air-cooling to below the lower critical range, and a second heating to a point below this range, followed by slow cooling to remove internal stress. In some cases, in crankshafts, for example, pins and journals are made hollow by removal of the core and, provided that this is done before heat-treatment, such a procedure is helpful and is to be encouraged.

The subject of crankshaft manufacture, heat-treatment and testing has been fully dealt with in the author's paper previously mentioned, but Dr. Dorey again emphasises that lack of mechanical work on a forging cannot be replaced by simple heat-treatment. Quick cooling is impossible in heavy forgings while slow cooling imposes a severe limitation on the mechanical properties.

Apart from the quality of the material the two most important factors affecting the strength of the shafting are:

(*a*) A knowledge of the actual stresses to which it will be subjected to in service; and

(*b*) the behaviour of the material when subjected to the known stresses.

In the case of the former it becomes necessary to use instruments and devices to be able to measure the actual stresses existing in shafting under working conditions. For a proper appreciation of the latter it is necessary to ascertain the behaviour of the material when subjected to the known stresses, both as regards magnitude and fluctuation and further, in certain cases, as affected by environment. This section of the paper is devoted to a consideration of the strength of mild-steel forgings, and, at the outset, it is mentioned, that the routine tests carried out on forgings are merely for indicating the general quality of the material, and if further information is required, there are a number of special tests which can, with advantage, be carried out.

Since the subject of this paper includes propelling shafting, reference is made to the effect of environment on the fatigue strength, this being more applicable to the screw shaft, although a few isolated cases have been brought to notice where crankshafts have suffered in this respect, screw shafts are therefore discussed in a short section. Considerable attention is also given to geared systems.

Summary on Crankshafts

Summarising the questions of the crankshaft, the author believes that bending possibly constitutes the most severe fatigue loading. It is shown that this is in the neighbourhood of approximately +5,000 lb. to −1,000 lb. per sq. in., giving approximately three tons per square inch. At stress concentrations this may approach a range of six tons per square inch.

Considering the material to be anticipated in shaft forgings, more especially in the case of semi-built shafts, and further, taking size effect and surface finish into account, the range which will just not break a shaft in reverse bending is probably about 13·5 tons per sq. in., giving a factor of safety of approximately 2·25. The author believes that these figures indicate clearly how desirable it is to eliminate as far as possible additional bending which may be caused by mal-alignment of axial vibration. A further point of interest appears when a comparison is made with the steam reciprocating engine. From seventeen cases considered, the stress due to binding varied from 1,740 lb. per sq. in. to 1,330 lb. per sq. in., and with correct valve setting this loading is not reversed on bottom dead-centre.

On the question of torque, it is indicated that speed variation possibly goes a long way towards reducing the fatigue loading, if torsional vibration is not present. If, however, torsional vibration is present, then depending upon the magnitude of the stresses induced, the resistance of the shaft is lowered in respect of binding fatigue. This is well illustrated by experiments carried out at the National Physical Laboratory.* These experiments yielded the following results:

$$\frac{f^2}{f_1^2} + \frac{q^2}{q_1^2} = 1$$

f and q denote, respectively, the applied bending and

* Gough and Pollard, "The Strength of Metals Under Combined Alternating Stresses." *Trans. Inst. Mech. E.* Vol. 131, 1935.

torsional stresses at the fatigue limit for reversed stresses. f_1 and q_1 denote, respectively, the fatigue limits under simple bending and simple torsion.

The equation may be re-written

$$f^2 = f_1^2 - f_1^2 \frac{q^2}{q_1^2}$$

from which it is apparent that f decreases as q increases, thus indicating reduced fatigue resistance to bending with increase of torsional fatigue. It is for this reason that the author desires to see torsional vibration stresses in the crankshaft reduced to a minimum.

Screw-Shafts

On the question of screw-shaft failures, Dr. Dorey referred to a paper which he delivered before the Institute of Marine Engineers* in 1935. The information contained in that paper may be briefly summarised as follows :—

(1) That the fatigue strength of steel is reduced in an environment of an oxidising nature.

(2) That the fatigue resistance is further reduced by a keyway.

It will be of interest to quote the experimental evidence in that paper supporting the above statement. With reference to point (1) above, it was pointed out that very considerable damage can be caused either by small ranges of stress continued for a sufficiently long time or large range of stresses at slow frequencies. Inglis and Lake,† testing a mild-steel specimen, found the bending endurance limit when tested in air to be about ± 17 tons per sq. in. ; but when exposed to simultaneous alternating stresses of ± 2·6 tons per sq. in. and drips of Tees water having a salinity of about two-thirds of that of sea-water, the specimen broke after $66{\cdot}4 \times 10^6$ reversals. To give a life of 10^8 reversals it was estimated that the stress would be about ± 1 ton per sq. in. From this it would appear evident that for ordinary commercial steels there is no corrosion-fatigue limit, and, given sufficient time, failure will occur under very low stresses. When it is to be remembered that the shafting of a vessel in service for 280 days a year rotates about 40 million times yearly with engines having a speed of 100 r.p.m., and that specimens used in corrosion fatigue tests are polished and of plain cylindrical form, the need for special care to prevent the access of sea-water to stressed parts, and particularly at points where there is a likelihood of stress concentration, is obvious.

Regarding point (2), the experiments carried out by Thum‡ showed that, under conditions of rotary bending fatigue, the fatigue limit for a plain cylindrical shaft was reduced by 41 per cent. when the shaft was recessed by end milling for plain parallel keys with ends rounded, the reduction of fatigue strength being 20% with sled-runner ends.

The conclusions to be drawn from the foregoing may be summarised as follows :—

(1) For reasonable life, sea-water must be excluded from steel screw-shafts, and great care is necessary in fitting the various devices employed for this purpose.

(2) Sled-runner keyways, carefully radiused at the bottom, should be employed for keying the propeller. Further, great care should be taken to ensure a good fitting key, and, in particular, the propeller should be "hard up" on the big-end of the cone. In this connection statistics available indicate that of the total number of screw shafts condemned per annum by the surveyors to Lloyd's Register of Shipping, no less than two-thirds are due to fractures observed at the keyways, on the cones, and at the after ends of the liners.

* "Marine Machinery Defects : Their Causes and Prevention."

† *Trans. Faraday Soc.* Vol. XXVI, Part 21.

‡ *Trans. N.E.C. Inst.* Vol. LI. Discussion on paper, "Relation of Fatigue to Modern Engine Design."

Colloidal Graphite for Assembly and Running-in

THE experimental facts regarding wear which have been uncovered in recent years are reviewed in a recent Bulletin[1], and an attempt made to analyse the nature of metallic wear in new bearing faces. A method, for instance, is described in which the profile of a bearing surface at various stages of running-in has been recorded with a magnification of 2,000 in the vertical and 32 in the horizontal. The high spots are shown being smoothed out in characteristically different ways with plain and colloidal graphited oils. Direct abrasion, in the presence of plain oil, is shown by the reduction of the high spots to a plateau-shaped configuration, whereas when the two opposite working faces are lubricated with colloidal graphite and come together due to load, surface irregularities or distortion, they create boundary conditions of lubrication in the oil film, and instead of rubbing one on the other, they rub on the microscopic plate-like particles of graphite.

The bulletin adduces the discovery of an amorphous skin formed on a rubbed metallic surface as an important contribution to knowledge of the wear phenomenon, stating that the process of running-in includes plastic deformation of the high spots and of abrasion, the preponderance of one or the other being determined very largely by the degree of protection afforded the faces in lubrication.

Having been associated with much of the research work described in this publication, E. G. Acheson Ltd. have correlated their own work on surface phenomena during lubrication employing colloidal graphite with the broader aspects of wear. Test results and curves are given, to show how colloidal graphite reduces wear and enables an engine, for example, to develop nearly its full power.

It is pointed out that it is now common practice to assemble, and run-in, with colloidal graphited oil such units as engines of all types, reduction gears, tractor equipment, machine tools, pneumatic equipment, compressors, magnetos, meters, and recording instruments.

The First Tinned Foods

NEW light on the origin and early products of the canning industry are given in a recent report[2] which comprises a reprint of papers recently read before the Food Group of the Society of Chemical Industry by Professor J. C. Drummond, and others.

The papers describe how a number of tins of meats and vegetables which had reposed in the Royal United Services Museum and the National Maritime Museum, London, were opened and submitted to chemical and bacteriological analysis. Two of the tins, one containing veal and the other carrots, had accompanied Sir Edward Parry, the Arctic explorer, on his famous expeditions in search of the North-west Passage in 1824, and when opened, they proved to be still in "what one could fairly call perfect condition." The reports of the various analyses are given in full detail with photographs of the actual cans. The first part of the booklet recounts briefly the discovery of the principles of the canning process by Nicholas Appert in France, and their adaptation by a celebrated English engineer and Vice-President of the Royal Society, Bryan Donkin, so that robust canisters of tinplate could be used instead of Appert's fragile glass jars. So successful was Donkin that within seven years Donkin's tinned foods factory at Bermondsey was supplying ten of thousands of large tins for Australian and Arctic expeditions,

There are some interesting sidelights on the theories advanced at the time for the success of the canning process, and also a report upon some dried vegetables in tins which were packed for the army during the Crimean War. Copies of this report may be obtained free of charge by application to : The Secretary, International Tin Research and Development Council, Fraser Road, Greenford, Middlesex.

1 Technical Bulletin, No. 112, issued by E. G. Acheson Ltd., Thames House, Millbank London, S.W. 1.

2 "The Examination of Some Tinned Foods of Historic Interest."

Contact Corrosion of Stainless Steel

By John Arnott, F.I.C.

Local attack on some types of stainless steels in contact with apparently innocuous non-metallic substances, under wet conditions, is discussed. The addition of molybdenum to the steel appears to reduce the probability of attack.

THE phenomenon which is the subject of these notes has been called "contact corrosion," for want of a better term. Briefly, it might be said to be a local attack on some types of stainless steels when they are in contact with apparently innocuous non-metallic substances while immersed in, or wetted by a liquid, such as sea-water, which, in absence of such contact, has no action on the steel.

Occurrence

Although some occasional examples had been observed over a few years, it was only recently that an outstanding case came to the writer's notice. In this instance, several similar parts on one ship were affected, and there was an ample supply of material for examination; a further advantage was that the working conditions were known.

The parts concerned were S 80 stainless-steel rods in reciprocating units, operating in cold sea-water. The rods as originally fitted where ground to a fine finish. The packing in contact with these rods was "greased cotton," and it was significant that the pitting was confined only to those portions of the rod which could come to rest in the packing; the ends which were constantly immersed in sea-water were in perfect condition. The pitting was very severe, although the rods as a whole were highly polished, and showed no general roughening. This can be seen by reference to Fig. 1.

The analyses of the rods were found to be quite normal and well within the limits of the S 80 specification.

Undernoted are the analyses of two of the rods:

	2¾-in. Rod. %		2-in. Rod. %
Carbon	0·20	....	0·18
Nickel	1·82	....	1·83
Chromium	16·10	....	16·13
Manganese	0·39	....	0·38
Silicon	0·48	....	0·47
Vanadium	None	....	None
Molybdenum	None	....	None
Sulphur	0·014	....	0·013
Phosphorus	0·017	....	0·018

The Brinell hardness figures of the two rods were 269 and 255, respectively.

A similar type of pitting, though not so deep, has since been observed on shafts in rotary units, at the packing glands. These were handling fresh water, and the period of contact was only a matter of hours. Again, there was no general attack; the shafts were perfect, except at the glands. The apparent mystery of severe pitting under such ordinary conditions led to the investigation of several factors, in order to find the range of steel affected, and some, at least, of the conditions conducing to the phenomenon.

Corrosive Agents in Contacting Materials

In the first instance, a careful search was made for corrosive agents in the packings or contacting materials. This nearly always gave negative results, and later experience has indicated that corrosion can occur with materials such as carbon, which are quite free from acids or soluble salts. The only exception was in the case of some leather packings which were found to contain a little free sulphuric acid.

Tests in Laboratory

It was found that contact corrosion could be readily produced in the laboratory by wrapping various materials round stainless steel bars, and submitting to complete or partial immersion in sea-water at room temperature. In all cases, the bars were ground before testing. Some preliminary tests were made on one of the rods returned from service. Sufficient was machined off the diameter to remove completely the pitted areas, and the rod was ground before test. The rod, with the various packings, etc., wrapped round it, was immersed to half its diameter in sea-water. It was given a half-turn daily.

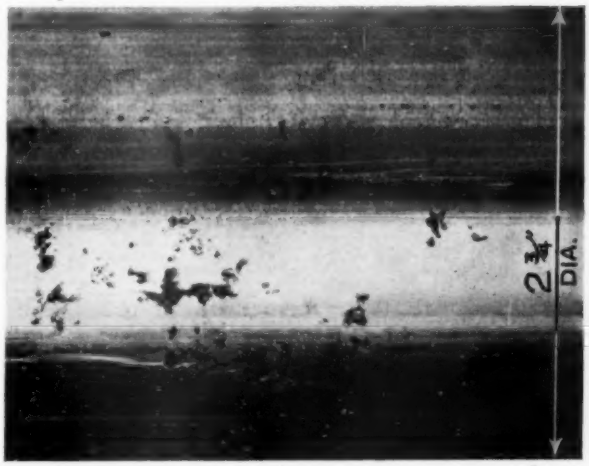


Fig. 1.—Showing pitting on highly polished stainless steel

The materials used for the tests were:

1. Some of the original packings returned from service.
2. Standard hydraulic packings. These are principally cotton impregnated with tallow.
3. The same, with a rubber core.
4. Carbon packing rings as used for steam sealing.
5. Leather, as used for packing in hydraulic machines.

All of these produced definite pitting, or roughening, inside a period of 10 days, and at room temperature. The extent of the attack varied, being least under carbon packing, and worst under leather. The attack with leather was a fairly uniform roughening. With the cotton packings, the carbon and the rubber, the attack was a localised pitting, exactly similar to that found in service.

It will be appreciated that the results of these tests cannot be given quantitatively. In cases of pitting, the amount of the metal removed is extremely small as a proportion of the whole. One is forced to rely on visual examination and fine differentiation is not possible.

Attack on Various Stainless Steels

A series of specimens covering several steelmakers was obtained. Pieces of bar about ¾ in. diameter were carefully ground and cleaned before test. Most of the tests were made by contacting with leather, since leather had proved to give the most severe attack. Many tests were, however, made with cotton packings, carbon and soft rubber. The general conclusions agreed with the results of the leather series.

The range of steels examined was:

Low carbon 12% chrome	S 61	As received	Brinell 207
Medium carbon 12% chrome	S 62	As received	,, 229
,, ,, ,, ,,	S 62	Hardened	,, 512
Medium carbon 16% chrome 2% nickel	S 80	As received	,, 286
,, ,, ,, ,, ,, ,,	S 80	Hardened	,, 460
16% chrom. 10% nickel	Austenitic	As received	,, 229
18% chrome, 8% nickel	Weld-decay-proof	As received	,, 179

After seven days' intermittent immersion in sea-water, the only specimens which were unaffected were the two austenitic steels. All the others were attacked at the area of contact. Under leather, they showed the general roughening; under the other materials they showed local pitting, just as found in the preliminary tests.

A set of four steels of the following analyses was obtained. These all came within the limits of the S 80 specification, but there was a range in chromium content.

	Carbon. %	Nickel. %	Chromium. %
1	0·20	1·85	16·7
2	0·18	1·68	17·4
3	0·18	1·76	17·7
4	0·20	1·86	19·7

In contact with leather, as before, these showed no noticeable difference in resistance to attack.

The effect of heat-treatment on the resistance to contact attack was next investigated. Several specimens of S 80 steel were tested in the "as received," and in the fully-hardened condition. As far as could be judged, the results were roughly the same.

Later a sample was obtained of a high chromium steel containing between 1% and 2% of molybdenum. This steel showed much less pitting than the ordinary grades of S 80. As it was very low in carbon content, it may not be exactly comparable to the other steels tested, but it does indicate one direction in which improvement may be found.

In the short-time tests which have been described the austenitic steels showed no attack. One striking example which came to the writer's notice, shows that even the austenitic group are by no means immune. This refers to a set of tubes 1·410 in. diameter, 0·032 in. wall thickness, which formed part of a milk cooler. The attack was entirely confined to a portion on the outer wall where a tight-fitting soft-rubber ring was fitted as a seal. The medium in this case was brine. Several tubes were perforated in less than a year, and the cutting action can be seen in Fig. 2.

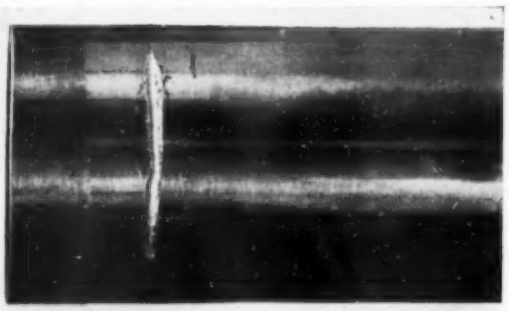


Fig. 2.—Stainless steel tube perforated by corrosion.

References

1. Of the references to "contact corrosion" in technical literature, probably the most detailed is that in Monypenny's *Stainless Iron and Steel*. Mr. Monypenny devotes several pages to experiences and experiments arising therefrom, and referring chiefly to ordinary 12–14% chromium steel. He mentions that the 16–20% chromium steels are probably less likely to be pitted, and the austenitic still less so. But, he makes it clear that entire absence of attack cannot be guaranteed with any of these steels under damp contacting conditions over long periods.

Mr. Monypenny suggests that greasy packings might help in avoiding the trouble. As has been seen earlier in these notes, this is not always the case. The commonest type of greasy packing is impregnated with tallow, and if the temperature of operation is low, this does not adequately cover the steel.

2. In *Metal Progress*, of June, 1938, there is an article on "Pit Corrosion of Stainless Steel," by Howard A. Smith. A description is given of a method of testing the susceptibility of various stainless steels by means of their response to a slightly acid ferrice chloride solution in a special circulating device.

It is rather surprising that an 18/8 stainless steel shows pitting under the conditions of test, while a low carbon 12% stainless steel—i.e., S 61 type does not. It would appear, therefore, that the test does not disclose liability to the type of contact corrosion dealt with in these notes.

3. The pitting of stainless steel is referred to in an article in *Korrosion und Metallschutz* of October-November, 1937. This refers to steel of 13–14% chromium, and it is stated that corrosion of spindles occurs on long standing in moist packing if the latter contains graphite. The use of steel of higher chromium content is recommended.

Conclusion

Contact corrosion, in the form of pitting, can occur when the hardenable, and even the austenitic stainless steels are in close contact with such substances as cotton, carbon and rubber in presence of sea-water and, to a lesser extent, of fresh water.

At present, one additive element which appears to reduce the probability of attack is molybdenum.

Acknowledgment is made to the directors of Messrs. G. and J. Weir, Ltd., for permission to publish this note; to Mr. J. Hunter of the laboratory staff, for enthusiastic help in its preparation; to Dr. Hunter, of the Clyde Alloy Steel Company Ltd., for supplying some of the steel samples, and to Mr. J. H. G. Monypenny, of Messrs. Brown Bayley's Steel Works, Ltd., for his kindly interest and experience in corrosion problems generally.

Another Record Copper Output in Canada in 1938

DURING the past year Canadian copper production established a new high output record, amounting to 585,521,538 lb., as compared with 530,028,615 lb. in 1937, an increase of 10%. Owing to lower average prices, however, the value, amounting to $57,876,000, was 16% less than in the previous year. Ontario is Canada's premier copper-producing province, the source there being the nickel-copper ores of the Sudbury district. Noranda is the outstanding producer in Quebec, other important mines in the same district being the Aldermac, Waite-Amulet and Normetal. At Eustis, Quebec, Canada's oldest copper mine was continuously operated by the Consolidated Copper and Sulphur Company, Ltd.

As a result of careful geological study, and a programme of diamond drilling, a copper deposit of major importance was reported as being discovered at the Waite-Amulet Mines, Ltd. This ore occurs at a depth of about 1,000 ft. below the surface, and present indications suggest an ore body of major economic importance, though some time must elapse before it can be developed ready for production. Copper concentrates at present coming from the Waite-Amulet and Normetal are being smelted at Noranda, and those from the Aldermac and Consolidated Copper and Sulphur Company, Ltd., are exported. A plant is now being erected at the Aldermac to produce elemental sulphur from pyritic concentrates, with a pure iron oxide as a by-product.

Smelter production by the Hudson Bay Mining and Smelting Company, Ltd., from ores of the Flin Flon and Sherritt Gordon mines was considerably above that of 1937. Production from the Britannia Mine, on Howe Sound, in British Columbia, was about the same as in the previous year, and the output of the Granby, at Copper Mountain, was greater than in 1937 as a result of continuous operations being maintained throughout the entire twelve months.

Some Aspects of the Non-ferrous Metals Trade

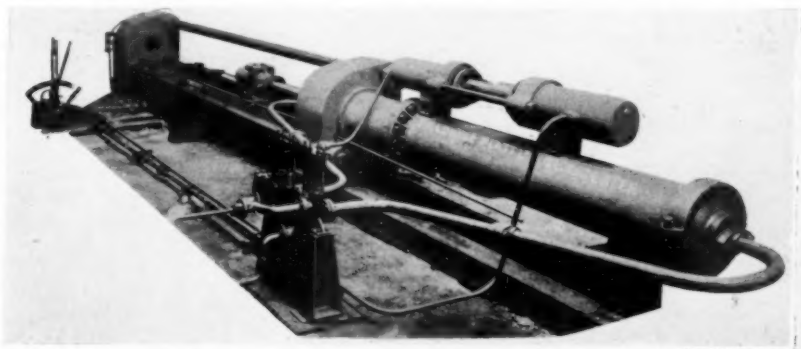
By Gilbert Evans

The increasing demand for non-ferrous tubes of various sizes is reflected in the many installations of plant for their production recently put into operation, or in course of construction. It is noteworthy that British plant for this purpose is finding increasing interest in many countries abroad, evidence of which is given in this article.

IN dealing with improvements and advances in non-ferrous plant at home and abroad, one fact stands out most prominently—that British practice in the manipulation of non-ferrous metals is being copied in most countries abroad, particularly in Scandinavia (including Finland), Turkey, United States of America, Italy, Spain and even Germany. The latest evidence of this is the fact that, under the direction of the writer, rotary piercing, extrusion and drawing plants, with suitable furnace equipment, have been supplied to Finspong Metallwerkes A.G., Sweden; Porsgrund Metallwerkes A.G., Norway, and others.

The press in these installations is a Fielding vertical extrusion press of 1,000 tons maximum power with a ram stroke of 2 ft. 4 in. It is designed for the manufacture of tubes in various non-ferrous metals and incorporates the Serck patent guide for the main ram to which the material is attached. The extrusion process is of the indirect type, the container moving in a downward direction during the extrusion of the billet. The maximum diameter of the billet used for tube extrusion in 6 in. dia. by 10 in. long, and the capacity of the press ranges from tubes of $\frac{3}{4}$ in. to 3 in. bore with a wall thickness of $\frac{3}{32}$ in. to $\frac{1}{8}$ in. bare. The controlling valves may be arranged on the press cylinder, or independently at the side of the press, and this unit forms a compact arrangement for producing tubes at the rate of 50 to 80 per hour.

The additional suggested drawing plant comprises a Fielding horizontal tube-drawing press of 170 tons, having a stroke of 18 ft. The main cylinder is of the double-acting type with an annular ram giving a return power of 75 tons for stripping the drawn tube from the mandril. To facilitate the starting of the tube the ordinary working pressure is increased by means of an intensifier supported on the main cylinder which increases the stripping power to 170 tons at the commencement of the stripping operation, reverting to the lower stripping power for completion. The cylinder ram is provided at the outer end with a sliding crosshead and swivel mandril holder. The crosshead is supported on a machined tank forming the bedplate, and the mandril holder secures the various size mandrels by means of a cotter capable of resisting the maximum power.

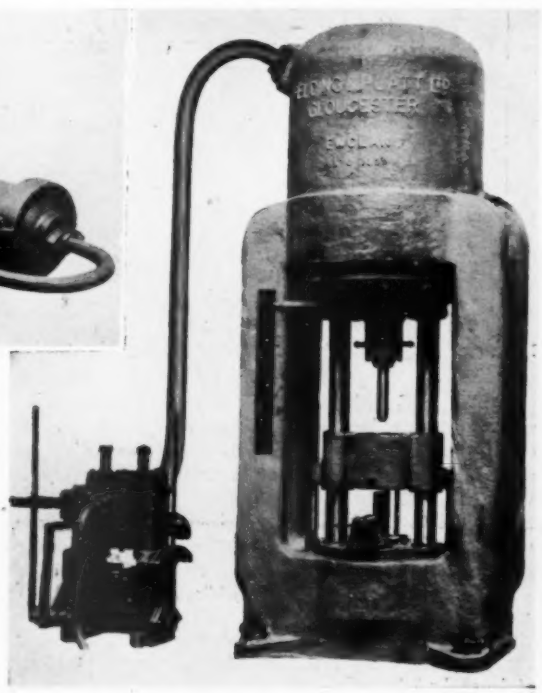


A Fielding horizontal tube drawing press of 170 tons, with a stroke of 18 ft.

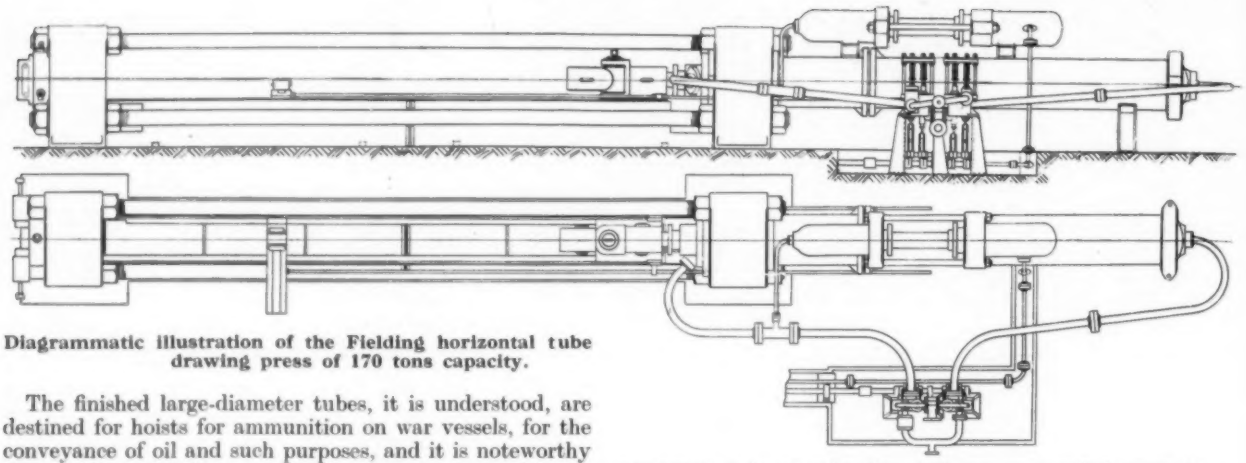
The bar or mandrel is also provided with a sliding support, which allows it to be drawn radially from the centre line of the press for the attachment of the billet, and return the same to the centre of the press for the drawing operation. The drawing dies are supported in the die-housing secured to the main cylinder by two horizontal tie-bars arranged diagonally for easier manipulation of the tools. A set of three-point contact rollers is attached for easing the tube on the mandrel during the drawing operation, and also a pair of hydraulic cylinders which control the movement of the stripping dies after the completion of the drawing operation.

Rotary Piercing Mills

A substantial order for four Evans mills has been placed in this country, for a firm in Finland. These mills are the author's patent, and are guaranteed to produce, by a combination of piercing and secondary expanding operations, shells of from $1\frac{5}{8}$ in. i/d up to 22 in., and under certain circumstances, to 24 in. i/d. These mills are the largest of their type in the world, operated by two direct-coupled motors of 500 h.p. nominal, and capable of withstanding a peak load of 100% overload for 45 sec. every two minutes. These particular units will be driven by "Asea" electrical equipment, as throughout Scandinavia it is understood that, as far as possible, home-produced equipment should be used. In British plants where these mills are installed the electrical equipment is by Metropolitan-Vickers Electrical Company Ltd.



A Fielding vertical extrusion press for non-ferrous tubes. Maximum power 1,000 tons.



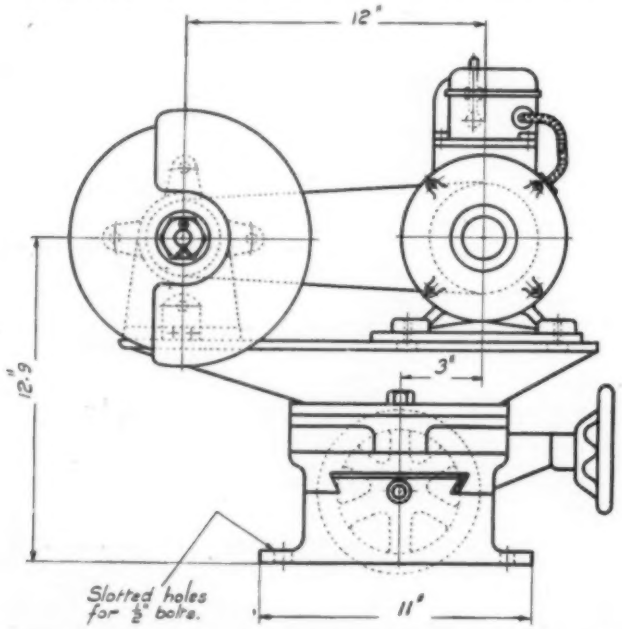
Diagrammatic illustration of the Fielding horizontal tube drawing press of 170 tons capacity.

The finished large-diameter tubes, it is understood, are destined for hoists for ammunition on war vessels, for the conveyance of oil and such purposes, and it is noteworthy that solid round billets, varying in diameter from 1¾ in. to 10 in., and weighing up to 18 cwt., are pierced and expanded to cover the range of tube diameters previously mentioned. Mention may be made of the fact that the heating chamber introduced by the author in 1914 has been adapted to every piercing unit which has been installed and manufactured by Messrs. W. H. A. Robertson and Co., Ltd.

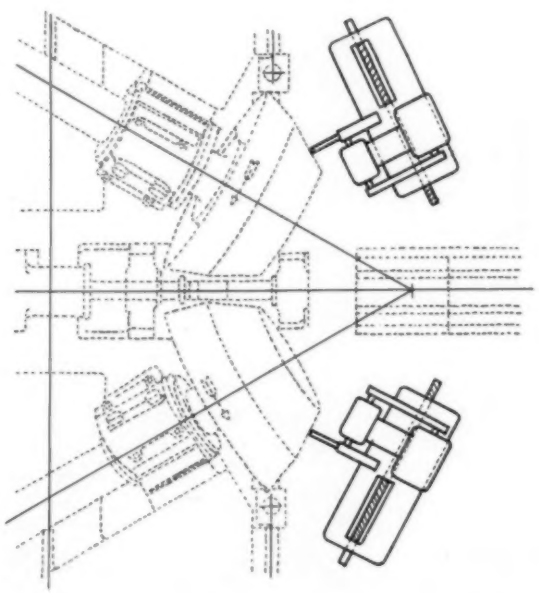
Plants of a smaller or more limited flexibility viz. 1⅝ in. to 8½ in. are being supplied to Messrs. The Wednesbury Tube Company Ltd., and a new branch of another non-ferrous concern for their new works in Scotland. An installation is also under consideration by a Russian firm in Moscow. This latter concern is planning a minimum total yearly output of 60,000 tons of tube, or 1,250 tons per week, and will necessitate at least three small piercing mills and two large units, plus one 1,000 ton and two 650-ton extrusion presses all working double shift. In addition, many draw-benches will be necessary together with subsidiary plant.

The latest improvement to these piercing plants is the grinding arrangement shown in the accompanying illustration. Manufactured to the author's design by Metropolitan-Vickers Electrical Company Ltd., it enables the working rolls to be reprofiled to templet without removal from their bearings in the traversing cradles, an economical factor which may later be adapted to the usual type of strip and plate rolls of non-ferrous mills. The most badly neglected pair of rolls the designer was called upon to reshape were treated and profiled in 2½ hours on a Saturday afternoon. Facilities are readily provided for mounting this equipment. This arrangement eliminates loss of output and expensive stripping of gears and transport to machine shop.

An interesting feature in seamless tube manufacture is that when dealing with solid steel billets in either the Stiefel or Mannesmann piercing process, the piercing mandrels have to be made from a special alloy steel to obviate seizure to billet, while in the non-ferrous process a steel of low carbon may be used to give an appreciable life, but here also a special carbon steel will give service over a much longer period.



New grinding arrangement for renewing the periphery of rolls in position.



The application of this new grinding arrangement to the Evans rotary piercing mill.

In the production of both ferrous and non-ferrous tube, it has been proved in practice that tubular bars to hold piercing mandrels are more dependable than solid bars, being more resilient to the sudden shocks at the contact of the solid with the piercing tool, and a further comparison is of interest in the displacement of the metal; in the treatment of steel, for instance, the piercing mandril is about 30-40% of the area of the billet to be pierced, while in non-ferrous work the area of the tool is exactly the same as that of the solid non-ferrous round billet. In the expanding process it is possible to increase the inside diameter of the non-ferrous shell by 2½ in. to 3 in., compared with

(*Continued on page* 236)

Per Capita Output and Labour Planning

As a result of statistical investigations which are given in Report 144 of the Committee for Works Economics presented at a recent meeting of the Verein deutscher Eisenhüttenleute, it is claimed that the number of men in the German iron and steel industry and their output per capita have reached a level of output not likely to be surpassed. Some aspects from this report are reviewed.

PRESENTED at a recent meeting of the Verein deutscher Eisenhüttenleute by Dr. Karl Rummel, of Düsseldorf, who is well-known in Great Britain, this report* is divided into two parts—"Economic Foundations" and "Statistical Figures of Numbers of Workmen and Per Capita Output in the Iron and Steel Industry." The first part will be dealt with here by only a short survey, although many ideas incorporated are worth considering from a completely different English aspect, the second, however, will be given more in detail as many results of the German development can be drawn from the figures and graphs, which may be interesting for comparison with English working conditions.

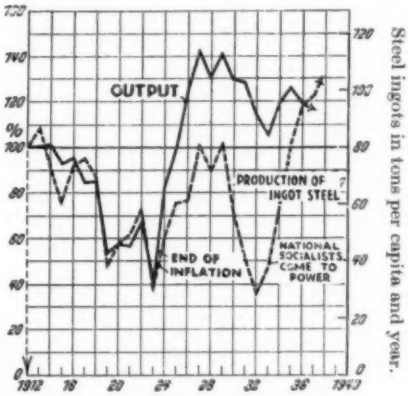
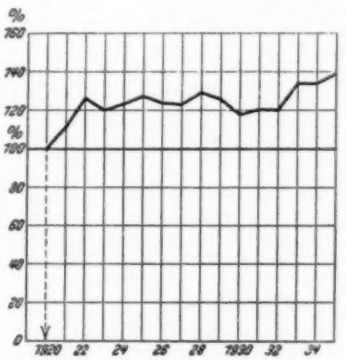

OUTPUT
PRODUCTION OF INGOT STEEL
END OF INFLATION
NATIONAL SOCIALISTS COME TO POWER
Steel ingots in tons per capita and year.

Fig. 1.—Output per capita and year of the total manning of the German iron and steel industry, 1912 to 1938, related to ingot steel. (Left) The year 1912 = 100%. (Right) Output per capita and year in tons of ingot steel.



The year 1920 = 100%

Fig. 2.—Output per capita and year of the total industry of U.S.A., 1920 to 1935.

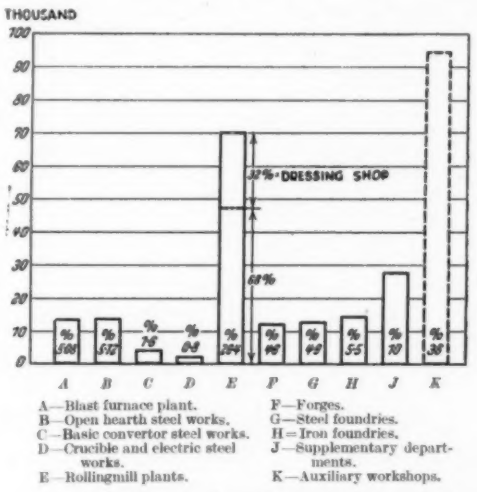


Fig. 3.—Distribution of the total manning of the German iron and steel industry in the various departments, 1938.

1. Each rationalisation results finally in an increase of the average output per capita. Generally speaking, it is possible to collect the means of increasing the output of individual work or the work of a whole nation into groups. The simplest way is by increasing the number of the employed and the prolongation of the working time of the individual workmen. Another well-known method is in avoiding loss of working time by loose running, waiting time, decided bottle necks in plants—i.e., harmonising the outputs of the various parts of a plant, etc., as well as increasing the intensity of work during the actual working time. No less important is the improvement in the quality of the products and of the methods of production. In the last respect the mechanisation is the strongest means for increasing the output per capita—i.e., the change from working by hand to working by machines. Here, however, some suppositions are necessary, if the mechanisation shall provide for economic results: a sufficient consumption of the increased quantity of production during the life-time of the mechanised plant must be guaranteed or at least assumed to be probable; the financial means of the individual undertaking as well as of the nation as a whole must be sufficiently liquid; and an inadmissible increase of unemployment must not be feared—i.e., at least the majority of the workmen unemployed by reason of the mechanisation must find other work in time. It should not be overlooked that otherwise the costs of unemployment may increase to such an extent that the part of unemployment insurance cost to be borne by the individual undertaking may counterbalance the profit resulting from the mechanisation, apart from all other direct or indirect damages of unemployment.

2. As statistical figures are used:

(*a*) The output per capita of ingot steel in tons per man and year. This figure increased nearly steadily in German iron and steel works from 1870 to 1912. The further development is illustrated by Fig. 1, which needs no further explanation. For comparison purposes, Fig. 2 is given showing the output per capita of the total industry of U.S.A. (i.e., not only of the iron and steel industry).

(*b*) The number of the persons occupied in iron and steel works. This figure is given as about 262,000 for April, 1938, and it may be of special interest to note how it is distributed over the various parts of the works, see Fig. 3. As would be expected, the rolling mill plants play an important role in the main departments; but it may be surprising to some what a great share of the whole is taken by the auxiliary workshops. This should certainly induce the engineer to pay more attention to this part of the works, which is usually not at the same high level as corresponding shops of, for example, the metal-working industry.

(*c*) The outputs per capita of the individual parts of the works as indicated in Fig. 3 show nearly the same trend as given in Fig. 1.

The following figures are deduced from these investigations:—

The output per capita of the *total works* of the iron and steel industry, exclusive foundries, per man and year, ingot steel—100 tons; of the *blast-furnace works*, exclusive of auxiliary workshops, per man and year, pig iron—550 tons (it can be supposed that this figure will decrease in the next year about 10%); of the *steelworks*, exclusive of auxiliary workshops, per man and year, ingot steel—400 tons; of the *rolling mill plants*, inclusive of finishing shops, but exclusive of auxiliary workshops, per man and year, finished products—100 tons (These figures will also be approximately correct for the year 1938).

* Report No. 144 of the Committee for Works Economics of the "Verein deutscher Eisenhüttenleute"; *Stahl und Eisen*, vol. 58, No. 44. 1938.

From these statistical investigations, it is concluded that the number of men in the German iron and steel industry and their output per capita, after years of long and nearly steady increase of this output, had reached a level, at the end of the last decade, which will probably not be surpassed ; more likely is it to experience a decrease. There are many reasons for this phenomenon—e.g., the increasing refinement in the quality of the products, the separation into more and more grades of material, the improvement of quality by further heat-treatment of the finished products, etc. Further mechanisation of the blast-furnace plants and steelworks will probably not result in any considerable increase of output per capita. At the rolling mill plants and in the auxiliary workshops, however, it will be possible, under favourable working conditions, to obtain a remarkable increase of the output per capita.

Surface Rolling of Aeroplane Propellers

The results of tests are given which were made to determine the main factors which reduce the fatigue strength of magnesium alloys.

THE trend of development in aeroplane manufacture has led, among other things, to a continuous increase in the size of propellers, and it is now considered that for large propellers aluminium alloys are already too heavy. In modern aeroplanes, however, stresses are sometimes high enough to cause serious failures in aluminium and steel propellers, and in order to avoid such failures slight changes have to be made in the design and assembly of the propeller and the engine. In many countries serious efforts have been made to introduce alloy propellers, on account of their lower specific gravity, but in most cases, where such alloys have been tried, failures have occurred. Such failures have resulted from the serious reduction in strength, due to corrosion and other factors, of high-strength magnesium alloys. Actual visible corrosion of magnesium alloys can be prevented by chromium treatment which is generally used, but this protection is not sufficient to bring wrought magnesium alloys up to a state that they can be applied with the same degree of safety as aluminium, steel, or other metals. Special methods have to be developed, and work in this direction has been carried out recently by G. Sachs.*

As a result of investigating a number of magnesium-alloy propellers used in competition with aluminium-alloy propellers where the former propellers had failed after a short time in service, and where the failures were due to fatigue and corrosion or erosion, it was concluded that deterioration had resulted from some combination of mechanical and corrosive attack in which the main factor was the sliding of the magnesium alloy on the steel, caused by the elastic vibrational deformations of propeller and hub. The fatigue crack in every case started where the shaft projected from the hub and the surface of the shaft around the broken surface was pitted deeply, especially at the starting point of the crack and the point opposite to it. Unbroken magnesium propellers, mounted in hubs were also pitted to a greater or less extent.

A number of small-scale fatigue tests were made to determine the main factors which reduce the fatigue strength of magnesium alloys using an alloy containing 8% aluminium, 0·5% manganese, and the balance magnesium. The standard fatigue strength for 10 million reversals of polished specimens was 10·27 tons per sq. in., while simultaneous corrosion with fresh water reduced the fatigue strength by 50%. Attaching a stiff collar around the central portion of the test specimen or using a cylindrical specimen in place of a specimen having a reduced central area reduced the fatigue strength to approximately 30%, a value which was not affected by simultaneous corrosion by fresh water. Additional experiments were made to find methods of improving the fatigue strength of specimens with collars or of cylindrical specimens. Chromate treatment had no visible influence, although it reduced wear appreciably. Thin, flexible collars with carefully-rounded-off edges and thin intermediate layers of fibre or similar materials gave somewhat higher fatigue values up to 50% of the standard value.

An effective method to improve the fatigue strength of parts which are subjected to an erosive action was found in surface rolling, which consists in deforming the surface skin of the material with one or several rolls, using a rolling pressure within such limits that the reduction in diameter is negligible. With polished test specimens treated this way, the fatigue strength was reduced slightly to 9·38 tons per sq. in., which is 90% of the standard value. Specimens with collars attached and cylindrical specimens had practically the same fatigue strength. The effect of erosion was counter-balanced completely by surface rolling, the improvement in eroded specimens amounting to 80% to 200%, while damaged specimens were improved to the same degree. Simultaneous corrosion with fresh water had no influence.

To confirm the results of small-scale experiments under conditions which correspond to those of practical application, a rolling process for propellers and optimum working conditions had to be evolved. A method for the surface rolling of propellers was developed, and experiments made on a full-scale special apparatus designed for determining the vibration characteristics of engines and propellers. On this apparatus, a systematic investigation was made with about 30 test-pieces of the magnesium alloy, consisting of extruded rods about 3 in. in diameter and 40 in. long. Two to four identically-treated specimens were subjected to stresses of different values, and the fatigue strength for 10 million reversals extrapolated.

The small-scale experiments were confirmed by those tests. Taking the standard fatigue strength as 8·04 tons per sq. in., a value determined from small specimens machined out of the large test specimens, the fatigue strength was reduced to 3·57 tons per sq. in., or about 45% of the standard value. Surface rolling partly eliminated this reduction, so that valves between 65% and 85% were obtained. The higher the rolling pressure, the higher was the fatigue strength, and damage of the surface had no influence. An intermediate layer of fibre increased the fatigue strength of the alloy, surface rolled under manufacturing conditions to about 85%. Fatigue strengths up to 7·14 tons per sq. in, or up to 90% over the value of untreated test-pieces were obtained under optimum working conditions, although practical conditions did not guarantee an improvement of over 50%. Such an improvement was also found in a later developed testing equipment with genuine magnesium-alloy propellers. With propellers of a larger size, having a shaft diameter of 4¼ in., as against 3 in., the improvement was about the same, although the actual test values obtained were very low. In experiments carried out without an intermediate layer of fibre, the surface of the shaft was worn badly, in one case as much as 0·040 in. diameter. Even then the fatigue strength of surface-rolled specimens was not reduced.

The factor which causes improvement in the fatigue properties, as a result of surface rolling, is not quite clear.

It has been suggested that there is some improvement in the properties of the surface layer by cold deformation. A more convincing theory considers as the main factor the building up of compression stresses in the surface layers by surface rolling, as these stresses are generally found to be very useful in overcoming the defects when tensile stresses and corrosive and erosive attacks occur simultaneously. Such compression stresses are actually created in surface rolling.

* *Metals and Alloys*, 1939, Vol. 10, No. 1, pp. 19 to 23.

Soviet Ferrous Metallurgy under the Third Five-Year Plan

By a SPECIAL CORRESPONDENT

Since considerable success has been achieved as a result of the completion of the two previous construction schemes carried out in the U.S.S.R., a third five-year scheme has been presented to extend ferrous metallurgy in the Union, and in this article an outline of the new scheme is given.

NO country has developed its ferrous metallurgy more rapidly than the U.S.S.R. during the period covered by the first and second five-year plans. The metallurgical enterprises controlled by the Commissariat of Ferrous Metallurgy fulfilled the second five-year plan by 114·5%. During the period there were put into operation 19 new blast furnaces, 52 open-hearth furnaces, 40 rolling mills, and 19 coking plant batteries. In the fulfilment of this plan a sum of over 7,800 million roubles was expended in construction in ferrous metallurgy. A second coal and metallurgical base was created in the East of the Union. As a result regions of the Urals and Siberia, which formerly consumed metals imported from other parts of the Union, are now producing more than enough to cover their own requirements. The completion of the plan had effected considerable changes in the geographic distribution of the metallurgical industry; new metallurgical centres were created in the East.

By the application of the most up-to-date technical processes, U.S.S.R. metallurgists increased the output of pig iron in 1937 as compared with 1932 by 2·5 times, the output of steel by 3·3 times, of rolled metal by more than three times, of coke and iron ore by 2·4 times.

The third five-year plan recently presented by Mr. Molotov makes still further provisions for the development of ferrous metallurgy in the Soviet Union. The tendency of the second plan to extend metallurgy to the East is to be followed up on a larger scale. Construction and production will be intensified in the Urals, a metallurgical base will be created in the Far East and in Western Siberia. The development of metallurgy will also be intensified in the centre of the Union. All this is expected to bring about a perceptible change in the weight of the different regions in the total volume of metal production, as is shown by the following table:

Weight of Different Regions in Total Volume of Metal Production (in percentages).

	South.		Centre.		East. (Urals, Siberia, Far Eastern Territory.)	
	1937.	1942.	1937.	1942.	1937.	1942.
Pig iron	63·3	55·9	8·1	8·4	28·6	35·7
Steel	56·1	54·1	9·9	10·4	34·0	35·5
Rolled metal	58·8	55·7	9·7	8·8	31·5	35·5

A considerable increase is contemplated in the proportion of quality and low-alloyed metals produced. The third five-year plan is to concentrate on special steels. Increases in production are provided for in respect of tubes, particularly of thin-walled, small diameter and specialised tubes. It is intended to achieve this not only by new productive capacity, but by the more efficient operation of plants with a view to eliminating certain disproportion in their working, by large-scale and small-scale mechanisation and by the development of the Stakhanov movement for the rationalisation of production and increasing the productivity of labour.

The amount allocated under the new scheme for investment in ferrous metallurgy is 9,250 million roubles—i.e., 27·5% more than was invested in ferrous metallurgy under the previous plan. The tendency to immensity in plants is to be abandoned. During the period under consideration it is proposed to put into operation 20 blast furnaces, 55 open-hearth furnaces and 32 rolling mills. As a result the capacity of the blast and open-hearth furnaces will be appreciably increased. This may be seen from the following suggested comparative figures:

	Blast Furnaces. Volume in Cubic Metres.	Open-hearth Furnaces. Area of Hearth in Square Metres.
1928	20,000	4,799
1932	36,900	6,701
1937	48,600	7,230
1942	70,000	9,767

The indices of utilisation of units it is hoped to achieve under the third five-year plan are shown in the following comparative figures:

	1932.	1937.	1942.
Coefficient of utilisation of volume of blast furnaces	1·75	1·10	1·0
Production of steel per square metre of hearth (in tons)	2·07	4·55	5·75

In 1942 (the concluding year of the new scheme) the contemplated output of pig iron will be increased, as compared with the last year of the previous scheme, 1937, by 52%, steel by 56%, rolled metal by 62%, quality rolled metal by more than twofold. It must be noted that 1% increase in production in 1942, in absolute figures, comprises a very different quantity from 1% increase in 1937; 1% increase in the production of pig iron in 1937 was 56,000 tons, in 1942 it will be 140,000 tons; correspondingly, the figures for steel are 42,000 tons and 137,000 tons, rolled metal 35,000 tons and 106,000 tons.

Blast Furnaces.—Out of the 20 new blast furnaces provided for under the new scheme, five are destined for the Southern works—Zaporozhstal, Azovstal and Krivoy Rog. All these blast furnaces are of super-capacity, with a volume of 1,300 cubic metres. Three of them are already in operation. In the centre of the Union a blast furnace will be put into operation at the Novo-Lipetsk works. Fourteen furnaces are being built in the East—10 in the Urals (two of which are destined for Khalilovo, for the production of chrome-nickel pig iron on the basis of local ore), two at the Petrovsk-Zabaikalsky works, and two at Komsomolsk-on-Amur. These figures indicate the special attention being paid to the development of ferrous metallurgy in the Eastern parts of the Union.

Open-hearth Furnaces.—The 55 new open-hearth furnaces will be distributed as follows: 14 in the south, 12 in the

centre and 29 in the east (the Urals, Siberia and Far Eastern territory).

Rolling Mills.—The geographic distribution of the 32 new rolling mills follows the same tendency as the distribution of open-hearth furnaces, namely, advance to the East, the satisfaction of local requirements in rolled metal by local plants. Blooming mills will be put into operation at the Krivoy Rog, Magnitogorsk and Novo-Tagil works. The assortment of rolled metal will be considerably increased, a new system of specialisation of rolling mills will be introduced with a view to reducing to a minimum the transportation of metals from long distances.

The new scheme makes provision for an increase in the capacity of tube production. New units capable of turning out 518,000 tons will be put into operation. The output of iron tubes in 1942, as compared with 1937, is expected to be increased by 76%, and of pig iron tubes by more than twofold.

Coke Industry.—Out of the 22 new coking batteries, eight are destined for the South, three for the Centre, and 11 for the East. The need to carry coke from the South to the Urals will be entirely eliminated (in 1937, 500,000 tons of coke were carried from the South to the Urals). The range of coal used for coking purposes will be increased from local supplies—Karaganda, Leninsk and other places. Coking experts are given a task of special importance, namely, to improve the quality of coke by means of decreasing its content of ash and sulphur. Provision is made for an intensification of the production of thermo-anthracite, and it is intended considerably to expand the chemical branch of the coke industry.

Iron-ore Industry.—In 1942 the output of ore is expected to reach 40 million tons, a quantity which will completely satisfy the requirements of the blast furnaces and steel-smelting production. The main problem will be to ensure for the metallurgical works a supply of ore from neighbouring regions. The blast-furnace shops of Lipetsk and Tula will be supplied with ore from local deposits, and the Novo-Tagil works with ore from the Tagil-Khishvinsk region. Exploitation will be started of a new iron ore deposit in the Far Eastern territory to meet the requirements of the metallurgical works at Komsomolsk. Manganese ore will also be supplied to the metallurgical enterprises of the East from eastern deposits.

Production of Refractory Materials.—In 1942, as compared with 1937, the production of refractory materials is expected to be increased by 40·3%. Improvement will be effected in the assortment of refractory products. The production of these materials will be considerably extended In the Urals and in the Far Eastern territory.

Joints for Steam Pipe-Lines

The higher steam pressures which are coming into increasing use for land power stations and marine steam installations have necessitated new investigations into steam pipe joints, in order to ensure that they will remain steam-tight under the required conditions of temperature and pressure. Messrs. F. J. Cowlin and J. P. Chittenden describe* the types of joints which have been used for steam pipe-lines, and tests which they have carried out to determine their suitability.

Diagrams illustrate fixed- and loose-flanged joints employing gaskets, loose-flanged joints employing seal welding, and welded type joints. An interesting form of seal is the Wills' joint ring, which consists of an hermetically-sealed circular tube containing an inert gas under pressure. The ring can be of copper, cupro-nickel, mild steel, Monel metal or other suitable material, and can be manipulated if necessary into other circular forms. The gas used liquefies at minus 146° C., and the internal pressure is varied to suit the service, a definite increase in resilience being obtained with increase of temperature. Pressures up to 20,000 lb. per sq. in. at room temperature have been held with this type of ring, and at 1,000° F. pressures up to 250 lb. It is claimed that the resilience enables the ring to be used over and over again, and the large number of tests made support this claim. A marine application of this joint occurs in the steamships *Alcantara* and *Asturias* of the Royal Mail Line, and on land in the Brighton power station.

The authors show ways in which the pressure of the fluid within a steam pipe can be made to provide either part, or the whole, of the sealing load. Hydraulic pressures up to 2,000 lb. per sq. in. were used to determine the relative efficiency of different kinds of gaskets.

Temperature plays an important part in the design of a steam pipe joint, and in the opinion of the authors, at temperatures over 800° F. there is little reason to doubt that the welded type of joint will replace the bolted type wherever considerations of accessibility and renewability permit. However, the difficulty of finding a really satisfactory test of the reliability of the weld still remains. Numerous methods have been investigated, including mechanical, magnetic, electrical, and X-ray tests, the last two giving perhaps the most promising results and being the two most commonly used. The principal safeguard appears still to rest in the skill of the operator, combined with rigid control of the welding technique and stress relief by heat-treatment after completion.

* In a recent paper before the Institute of Marine Engineers.

Tin Researches

THE mechanical polishing of metal specimens for microscopical examination has to be carried out with extreme care to avoid deforming the structure but where the metal is a soft one like tin, it has hitherto been practically impossible. A method which avoids the use of abrasives has been devised by P. A. Jacquet, and is now described in Technical Publication No. 90 of the International Tin Research and Development Council. The specimen with cast or roughly-sawn surfaces is made the anode in a concentrated mixture of perchloric acid and acetic anhydride or acetic acid. The time required may be as long as 40 mins. in the case of a roughly-sawn surface, but with a cast surface a high polish can be obtained in from three to four minutes. By following with a short electrolysis at a lower current density the crystals can be etched more or less deeply and become well defined.

Application of these methods has enabled the author to show that abrasion with fine emery, as in mechanical polishing, may produce a false structure to a depth of a quarter of a millimetre. The new structure consists partly of small crystals formed by recrystallisation and partly of needle-shaped "cold-working figures." A great difference was observed between the structures of tin ingots of very high purity and of commercially-pure tin. The numerous photomicrographs reproduced are remarkable for their fine detail for the crystal structures.

Tin plating by the alkaline stannate method requires the production and maintenance on the tin anode of a film of oxides in order that the deposit shall be bright and hard and that the process shall be efficient. The composition and properties of the anodic films produced under all possible conditions have been investigated by Dr. R. Kerr, and a report of this work is now issued as Technical Publication No. 91 by the International Tin Research and Development Council.

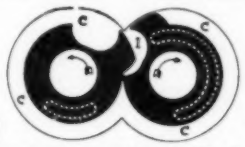
Anodic films such as are utilised in the alkaline stannate bath are greenish yellow in the bath, but change to orange outside and also decompose. They consist principally of hydrated stannic oxide with some stannous oxide; they may be dyed for decorative purposes and are completely soluble in alkalis. Brown films contain less stannous oxide, cannot be dyed and are less chemically active, while black films have good resistance to moist air and hot water and have decorative possibilities for tinplate and pewter.

Copies of the above publications may be obtained free of charge from the International Tin Research and Development Council, Fraser Road, Greenford, Middlesex.

Recent Developments in Materials, Tools and Equipment

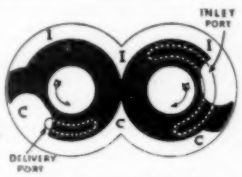
Rotary Exhausters and Compressors

THE vacuum pumps and air compressors made under the Northey-Boyce patents have a unique principle; they are rotary machines with positive action, and can be supplied with or without lubricated rotors. Pistons and rings, connecting rods, sliding vanes, valves, and eccentric drums are eliminated. The two rotors have fixed clearances in their working chambers, and there is no frictional contact. They can be run at high speeds and medium pressures without any working chamber lubrication. The gases or air handled in many processes, and which comes into contact with the material under treatment, may have to be free from any suspicion of oil vapour. In the Northey-Boyce oil-free type compressors the air is free from oil from the beginning, and there is no need for oil traps and filters. It must be admitted that slightly less air is delivered from an oil-free compressor than from a corresponding lubricated type, for the same power input, but it would be justifiable to regard this loss as the extra cost of oil-free air.



1

Commencement of Cycle: (a) Inlet port about to open into induction space "I." (b) Compression commencing in space "C."



2

(a) Induction well advanced in space "I." (b) Delivery commencing from space "C."

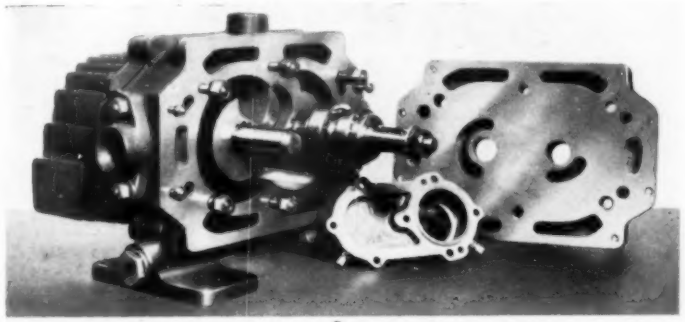
3

(a) Induction complete. Inlet port shut off from space "I." (b) Delivery complete. Small portion of compressed charge trapped in space "C."

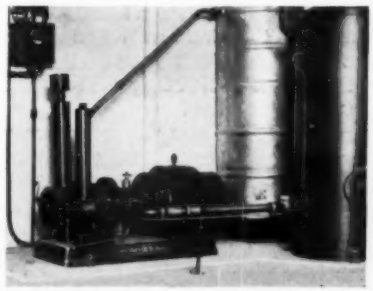
4

"Change-over" position. Seal broken between rotors, freeing undelivered air into induced charge, thus supercharging it before compression. Cycle recommences at (1), with induced charge now transferred to "Compression side" of rotor tips.

Dual-purpose machines that can be used as compressors or vacuum pumps alternately, with change-over valves, can be supplied. These, too, can be of the lubricated or oil-free types. Single-stage compressors are made in a range of 17 sizes, from 10·75 to 890 cub. ft./min. displacement, speeds from 2,400 to 1,000 r.p.m., and normal pressures ffrom 45 lb. to 80 lb. for the lubricated models, the oil-free types being from 40 lb. to 60 lb. pressure. There are six sizes of two-stage compressor, delivering pressures of 60 lb. to 110 lb., including one model for high-altitude use only. Seventeen single-stage vacuum pump models are listed, with similar displacement features and speeds as for the compressors, the maximum vacuum on closed circuit of within $\frac{1}{2}$ in. Hg. of absolute for the 16 larger machines, and within 0·5 mm. Hg. of absolute for the seven two-stage models.



The compressor opened, showing the small number of parts and the simplicity of construction.



One of the oil-free compressors as installed in a London factory.

The diagrammatic illustrations show the principle of operation, and it should be noted that the air trapped in the clearance volume is not re-expanded during the induction stroke, but the trapped air is released into the induced air only after induction has been completed and the new charge has been sealed. During the transition stage, from position 4 to position 1, the ports are closed and the contents of the casing are at uniform pressure. This eliminates any need for a seal between the rotors, large clearances are given, and the rotors do not touch or wear each other. The rotors are free to float endwise on their shafts, taking position between the end covers and touching neither.

The shaft seals, which are virtually the only wearing party, are readily replaceable. Spring-loaded, metal-backed mouldings of heat and oil-resisting composition are used for the smaller machines, and the larger machines have carbon-ring-and-bellows type seals secured in the cover castings and working on mirror-finished hardened seal-plates trapped against shoulders on the shafts.

Designed by Northey-Boyce, engineers, these compressors and vacuum pumps are manufactured by the Metropolitan-Vickers Electrical Co., Ltd., at Sheffield. Both air and water-cooled types are produced.

A Lubricant for Rubber

ONE of the problems of rubber parts subjected to friction has, up to now, been their lubrication. Ordinary lubricating oil cannot be used, because it tends to attack rubber, while many of the alternatives in general use have some disadvantage or other. Water is frequently used in, for instance, rubber or rubber-bonded bearings, but obviously cannot be employed by itself where it will drain away or evaporate.

There is a growing use in industry of natural and synthetic rubber as a bearing material. Bushes, shackles and other parts made of this material are creeping into wider use, while the duties of packing rings, belting and other applications has been successfully discharged by rubber for some

time. Alongside this development has grown the need for a suitable lubricant, and readers will not be surprised in this connection to hear that colloidal graphite, with which they are already familiar, is rapidly becoming standardised. Colloidal graphite as a dispersion in water has for some time proved of inestimable value in rubber bearings, and prompted by this and other experience, a patented lubricant has been developed consisting of the "dag" product in glycerin and water.

The glycerin and water, themselves lubricants, act as a carrier for the microscopic particles of graphite. The latter form a slippery surface on the rubber which provides not only highly efficient lubrication but lasting lubrication. In addition, however, the rubber is protected from much oxidation and from abrasive wear, and kept in good condition. Being extremely small, the particles of colloidal graphite can penetrate into interstices such as joints and connections, so preventing squeaking, an important factor in automobile spring shackles and bushes, for instance, which are exposed to the atmosphere. A further advantage is that colloidal graphite can be obtained in various dispersions. This patented lubricant is a product of the firm of E. G. Acheson Ltd., Thames House, Millbank, London, S.W. 1, from which full technical information is available.

Concentration of Sulphur Dioxide and Reduction of Sulphur Dioxide to Sulphur

IN 1934 Imperial Chemical Industries Ltd. patented a process for the production of 100% SO_2 from weak SO_2 gas by the use of a solution of basic aluminium sulphate. A plant with a capacity of 50 tons per day of liquid SO_2 was built in Finland and has been in commercial operation since 1936. A similar plant, with a capacity of five tons per day, is working near Manchester. I.C.I. also worked out and patented a process for the reduction of concentrated SO_2 to sulphur, by means of coke.

Prior to this Bolidens Gruvaktiebolag had developed a process for the direct reduction of weak SO_2 from smelter gases, and this process has been operated for several years at their mine in Sweden, with a production up to 70 tons of sulphur per day.

In view of the complementary nature of these processes an agreement was formed in 1936, whereby the patents and processes of the two companies were pooled, and a company formed as Sulphur Patents Ltd., to act as sole agent to negotiate licences for processes owned by the two companies. The Chemische Industrie, Basle (Ciba) had, about the same time, devised a process for concentrating SO_2, in which the absorbing medium was an emulsion of aromatic-amino in water. An agreement was come to with the Metallgesellschaft, of Frankfurt, under which this process was developed on a manufacturing scale, and Lurgi Chemie (a wholly-owned subsidiary of Metallgesellschaft) has built a plant in Germany with a capacity of five tons per day of SO_2, and one in France with a capacity of 30 tons.

Lurgi Chemie also worked out a process for the reduction of such concentrated SO_2 to sulphur. Hitherto, the two groups (I.C.I./Boliden and Lurgi/Ciba) have worked in competition in the filed of the concentration of SO_2, and its reduction to sulphur.

It has now been agreed that the patents and processes in this field, owned by all four companies, shall be pooled. This will enable the best process or combination of processes to be applied to each particular problem. In view of the fact that Lurgi Chemie is a company whose specific object is the design and construction of chemical plants, it has been agreed, by the members of the pool, that the exploitation of the processes shall be placed in the hands of Lurgi Chemie. Inquiries, therefore, in connection with the processes should be sent to Lurgi Gesellschaft fur Chemie und Huttenwesen m.b.H., Lurgihaus, Gervinusstr. 17/19, Frankfurt A.M., Germany.

Molybdenum Orange Pigments

MUCH work has been done in connection with the development of a formula which will give satisfactory results for the production of molybdenum orange pigments—a result that is eminently desirable on account of the unusual range of covering ability, colour brilliance, and non-fugitive strength of these pigments, particularly for their application in the paint and printing-ink trades. The yellow precipitate, produced by the addition of a solution of a bichromate, a sulphate, and a molybdate to a soluble lead salt solution, can be converted to an orange and to a red by sequential stages, depending on the conditions existing in the solution during and after precipitation.

In a study by Arthur Linz,[1] it was found that molybdenum oranges with the most desirable properties are produced under the following conditions:—(*a*) In the presence of lead salts in excess; (*b*) at room temperature or lower; (*c*) at low concentrations (0·1 molar); (*d*) precipitation in solutions in which the final *p*H is about 4·0–5·0; (*e*) the development of colour in solutions of *p*H, 2·5–3·0; (*f*)formation of aluminium hydroxide film on the particles to decrease oil absorption and increase brilliancy; and (*g*) drying at temperatures as low as possible, up to 100° C.

The lead sulphate can be replaced by borate, perborate, silicate, iodide, ferricyanide, cyanide, nitro-prusside, carbonate or chloride, and ferri-cyanide was found to give the best results of these alternatives.

Tetragonal mixed crystals of lead chromate-lead molybdate could be produced without any agent other than an excess of soluble lead salt and those used in controlling *p*H, and in this case the mixed crystals have the same desirable properties, but are less red and less stable if subjected to long stirring, washing or drying. A valuable fact emerges—that the ratio of molybdate to chromate should be about $1PbMoO_4$ $9PbCrO_4$, with approximately 10% excess soluble lead salt, for the production of lead chromate-lead molybdate colours.

One experiment showed that a slightly soluble salt of lead promotes stability of molybdenum orange, although not essential to its formation, but the colour is less red when chromate and molybdate are used alone than when sulphate or other slightly soluble lead salt is used.

It was shown as far back as 1863 that it is possible to obtain homogeneous crystals in the tetragonal form from mixtures of lead molybdate and lead chromate, and that such crystals were deep red, darker than crystals of pure lead chromate. The influence of *p*H on the process is particularly marked, and is discussed in detail; either too low or too high *p*H producing a yellower and less desirable colour—when too high there is no transformation from yellow, and when too low the transformation continues from yellow to red, but back to yellow again.

On Magnetic Methods of Testing Material

As magnetic methods of testing material are still criticised very differently, Franz Wever and Henrich Hänsel[2] have made numerous experiments in order to determine the limits within which these methods can be applied with advantage and sufficient positiveness.

At first the comparatively simple foundations of the method—strewing iron powder over the test-pieces or dipping the test-pieces in fluid of iron content during magnetisation,—and the experimental apparatus are described; further, the sensibility of the method is investigated, especially the penetration effect—i.e., failures which are not recognisable at the surface,—and finally a series of practical examples are given.

As a result, it can be considered that this non-destructive method of testing material is a sensible and reliable auxiliary for finding surface defects, and to a limited extent, even internal defects, if it is applied carefully and critically.

1 *Ind. and Eng. Chem.* 31-3-298/306.
2 *Mitteilungen aus dem Kaiser-Wilhelm-Institut fur Eisenforschung zu Düsseldorf, vol XX, No*

Reviews of Current Literature

Metals

COMPRISING two massive volumes, this book is of an outstanding character, and can be regarded as a *big* addition to the literature on metallurgy. It describes the characteristics of metals and explains how they are related to composition and treatment on the one hand and properties on the other. The arrangement of the matter in this order is particularly suited to such a comprehensive work as this, and it is presented in such an informative manner that anyone with some scientific or technical training, but with relatively little previous education on metals, will obtain a knowledge of the subject from the early chapters and be able to build on a sound basis as a study of the book proceeds.

As the title of this book implies, it is concerned with metals and not with preliminary work, such as ore concentration, extraction, refining, and alloying operations. Brief reference is made in the introductory chapter to these operations and to the occurrence of metals, but in the main it begins with metals formed subsequent to these operations, when the metals are capable of useful application. It is with properties, nature, treatment, and composition of metals, and the relations between them, that this book is concerned. Thus it is of particular interest to users who must of necessity select the metals most suitable for their purpose.

The characteristics of a sample of metal comprise its composition, constitution, microstructure, crystal structure, and condition, and the authors describe each of these separately and trace the relations between them. Treatment involves casting, hot-working, cold-working, heat-treatment, and surface treatment, and these operations are also described individually and the relations between them shown. Finally, the authors explain how composition and treatment influence the characteristics, and how these in turn influence the mechanical, chemical, electrical, magnetic, anti-frictional, and other properties.

In addition to the two volumes into which the book is divided, each volume is sub-divided into parts. Thus, Part I describes the characteristics of pure metals, such as iron, copper, aluminium, lead, zinc, nickel, tin, etc., and it proceeds to deal with the microstructure and crystal structure of these metals ; their behaviour when subjected to the action of force ; with the effect of force in producing deformation and fracture ; and with the relations between these. This section deals with one of the most important aspects of the subject in so far as the industrial uses of metals are concerned, since, in working operations, metals are required to deform easily without fracturing, in service they are required to resist both deformation and fracture, while in tests they are subjected to conditions that may produce both.

Other factors that affect the properties of metal are discussed in Part II, which is devoted to what the authors refer to as the theory of alloys—i.e., constituents, constitutional diagrams, structures, changes in solid metals and alloys, the effect of the rate of cooling, etc., on these changes, and the general relations between constitution, structure and properties. In connection with these relations, it is, of course, explained that they cannot be isolated from other factors that affect properties. The properties are related to the nature of a metal—its composition, condition, constitution, microstructure, and crystal structure,—and the last four are in turn related to composition and treatment—casting, hot-working, cold-working, and heat-treatment.

In Part III particular attention is directed to the mechanical properties of metals and their resistance or susceptibility to chemical attack by the environments to which they are exposed. All the quantitative data on the mechanical properties of metals are obtained by means of tests, and the relation between these data and behaviour in service are very complicated, and the validity of test results rests on a combination of several factors, but mechanical tests, which are discussed, give results which are used for a variety of purposes. The manner in which a metal reacts when in contact with a variety of solids, liquids and gases is discussed in the second section of this part.

The concluding section in the first volume is concerned with treatment and its influence on the characteristics and properties of metals. The authors discuss casting and particularly the important phenomena associated with this operation—such phenomena as the solution and evolution of gases, the mechanism of solidification in moulds, normal and inverse segregation, and shrinkage—and proceed to deal with heat and mechanical treatment and related operations. The chapter dealing with the latter factors begins with an account of the production and elimination of internal stress, and then proceeds to describe the plant used, the general technique involved, and the phenomena associated with heat and mechanical treatment. Attention is given to the effect and control of furnace atmospheres, the operations of rolling, forging, extrusion, drawing, pressing, etc., and the influence of treatment on the metal. Most of the subject matter contained in the first volume relates to metals in general, but in the preparation of the matter the authors had in mind the industrially important metals—iron, copper, aluminium, nickel, lead, zinc, tin, and magnesium, and alloys based upon them. With the exception of steel and cast iron, which are alloys of carbon, most industrial alloys are formed by the mixing of these metals, but much importance is attached to alloys formed by the addition of other metals or non-metals to one or more of the metals mentioned, and in the two succeeding parts, which comprise the second volume, although primarily concerned with the alloys based on these metals, about thirty other elements, present either as impurities or for specific purposes, are discussed.

The first part of the second volume is concerned with the industrial alloys based on iron—i.e., with carbon steels, alloy steels, and cast irons. In dealing with these particular attention is directed to the equilibrium relations between iron and carbon, as represented by the iron-carbon diagram ; to the effects on these relations of variations in the rate of cooling, temperature of heating, etc. ; to equilibrium relations between iron and the elements usually present in carbon and alloy steels ; and also to ternary systems involving iron, carbon, and another element, and iron and two elements other than carbon. The effects of heat-treatment on the changes that occur in these binary, ternary, and certain more complex alloys are discussed, and the general relations between composition and heat-treatment on the one hand, and constitution and structure on the other, are considered.

The properties of steels are, to a large extent, related to their constitution and structure, and through this to their composition and heat-treatment, but other factors affect the properties of steel, most of which are considered in the first volume under " condition." Another factor, however, that of " quality," is discussed in the part under consideration. This factor of quality depends to a large extent on the steelmaking process—materials used, type of furnace, details of operation, and particularly on the deoxidation procedure,—but the authors consider that a description of the intricate relations between quality and steelmaking practice as being outside the scope of this book, and confine their discussion of this factor in terms of characteristics discernible in the solid metal. Attention is therefore directed to the effects of inclusions on quality and the influence of additions of aluminium. In considering this factor the authors state it is probable that when the effects of inclusions, of oxygen in solution, and of aluminium additions have been thoroughly investigated, it will be possible to establish a direct correlation between steelmaking practice, characteristics discernible in the solid steel, and its behaviour in treatment, testing, and in

service. The element of mystery that now surrounds quality will then have disappeared entirely.

The second part of the second volume is devoted to copper, aluminium, nickel, lead, zinc, tin and magnesium and their alloys. Major attention is given to copper and its alloys, whilst the remaining metals and their alloys are dealt with. It is in these two latter parts that the general relations between characteristics, treatment, and properties become evident, and although they may be considered independently of the remainder of the book as descriptions of industrially important metals and alloys, they must be regarded as illustrating how all the factors dealt with in the first volume are related.

This book presents a faithful report of the present state of knowledge of metals in general use, and so ably is the subject presented that it will assist the student of metallurgy or engineering to obtain a comprehensive understanding of the progress in this field. In addition to students, however, this book will be found invaluable to all those who are professionally interested in specific aspects of metallurgy and who desire to improve their education on the subject as a whole. It will undoubtedly be regarded as a textbook on metals and become a source of information for all who study the characteristics of metals and how these are related to composition and treatment, and to properties. The book is complete with extensive references, an index to authors, and a valuable index to subjects. It is admirably produced, and can be regarded as a very valuable acquisition for all interested in metals.

By Sir Harold Carpenter, M.A., A.R.S.M., Ph.D., D.Met., D.Sc., F.R.S., and J. M. Robertson, Ph.D., D.Sc., A.R.T.C.; published by Oxford University Press, Amen House, Warwick Square, London, E.C. 4. Price £5 5s. net per set.

The Testing of Metallic Materials

Every year the importance of accurate test methods is of greater significance, and there has been a great improvement in both methods and apparatus. In this book the author has endeavoured to cover the whole field of mechanical testing, with an explanation of modern methods and their underlying principles, including information on the relation between various tests and descriptions of representative machines and instruments thus employed.

The first section deals with fundamental laws, tensile tests, gauge length, and special attention has been given to the important factor of proof stress. The second section is concerned with tensile machines of single- and multi-lever types; the next two chapters cover hardness tests in detail, including principles of various tests, comparisons and relationships; and the final chapter describes extensometers, ductility tests, wire-bending machine, magnetic tests, torsion test for wire, tensile tests at high temperatures, and the Hounsfield tensometer.

There are 46 illustrations and an appendix containing three conversion diagrams.

By E. Skerry, M.I.E.I. Published by Bunhill Publications, Ltd., 2, Bloomsbury Place, London, W.C. 1. 3s. 6d. net.

Journal of the Institute of Metals

Volume LXIII, 1938.

The high standard set by the Institute of Metals in the subject matter of its papers is well maintained in this volume of its half-yearly *Journal*, which contains 16 original papers, nine of which are followed by discussions.

The three first papers in the book deal, respectively, with an interesting case of corrosion-resistance of aluminium roofing sheet, oxidation-resistance in copper alloys, and the tarnishing of silver and its alloys and its prevention.

The next papers in the volume are devoted to researches on the age-hardening and other characteristics of the 4% copper-aluminium alloy, the mechanical properties of tin-rich antimony-tin alloys, and the effect of tellurium on the mechanical properties of pure tin. There is then a series of papers on the constitutions of various alloy systems and dealing respectively with aluminium-zinc alloys: the intermediate phases in the aluminium-copper system after slow cooling, and others of equal importance.

A paper by Hume-Rothery and Raynor, on "Factors Affecting the Liquidus, Solidus, and Solid Solubility Curves in Some Alloys of Magnesium," represents an attempt to bring order out of a mass of data on alloys.

Edited by S. C. Guillan. Published by the Institute of Metals, 4, Grosvenor Gardens, S.W. 1. 31s. 6d. net.

Sampling and Analysis of Carbon and Alloy Steels

In a new book on sampling and analysis of carbon and alloy steels the various methods of sampling are described in adequate detail, followed by a comparatively brief but explicit account of qualitative and quick tests for identifying various types of steel. The many methods for the determination of carbon are next given, and the other methods of analysis include description of the two variations of the gravimetric method—by direct weighing of carbon dioxide, and by weighing carbon dioxide as barium carbonate—and the volumetric method.

Fourteen pages are devoted to the subject of chemical separation, and the bulk of the book deals in a clear and authoritative manner with the determination of specified elements; these being—manganese, phosphorus, sulphur, silicon, copper, nickel, chromium, vanadium, molybdenum, titanium, aluminium, arsenic, tin, cobalt, tungsten, uranium, zirconium, colombium and tantalum, selenium, boron, beryllium, nitrogen, zinc and cerium.

In each case methods and procedures are included, the uniform style and logical subdivision of subjects adding to the value of a book, whether viewed from the point of view of study or as a reference work. The latter aspect deserves emphasis, for the detail in which each phase of its subjects is treated in these 356 pages makes this a decidedly valuable work of reference.

The four appendices alone contain a wealth of information, and readers will find much scope for reference in those sections. The third appendix, for instance, contains tables for preparation of indicator solutions and of the relations of hydrogen ion normality to pH value, together with a diagram showing hydrogen-ion concentration and colour changes of organic chemical indicators.

By the Chemists of the United States Steel Corporation. New York: The Reinhold Publishing Corporation. London: Chapman and Hall, Ltd. 22s. 6d. net.

Index to the Literature on Spectro-Chemical Analysis

Based on work which has continued over many years in the Spectroscopy Section of the National Bureau of Standards in Washington, this publication, the information for which was compiled by W. F. Meggers and B. F. Scribner of the Bureau, contains a listing of over 900 references on chemical analysis by means of atomic emission spectra. While various reviews in the past have given references to particular applications, this is the first general comprehensive index to spectrochemical literature. It should be of much significance to those concerned with this field. All items are arranged in chronological order with titles given in English (book titles have not been translated, however). References to published abstracts are given. Of particular interest is the detailed index which indicates most, if not all, of the literature pertaining to a particular application, determination, instrument, method of similar topic. Each reference is numbered, these numbers being used in the index.

Copies of this 65-page publication can be obtained from A.S.T.M. Headquarters, 260 S, Broad Street, Philadelphia, at $1, in heavy paper binding.

Some Applications for Heat-resisting Nickel Cast Iron

Under modern conditions, with higher temperatures and loadings becoming more common, the usefulness of ordinary cast iron for heat-resisting applications is strictly limited, and the use of alloy cast irons, which resist growth and maintain stability at elevated temperatures, is necessary to ensure satisfactory service.

ORDINARY cast iron has long been regarded as sufficiently heat-resisting to ensure stability and a useful life, but under modern conditions, when increasing temperatures and loadings are becoming more common, the field for ordinary cast iron is more definitely limited, since above certain temperatures it is not sufficiently reliable to ensure satisfactory service for a reasonable time. At elevated temperatures cast iron components may fail, due to loss of strength ; more frequently, however, failure results from structural changes in the metal which lead to growth and decay, followed by distortion and perhaps ultimate fracture.

The generally accepted theory for the volume changes in cast iron when heated repeatedly to high temperatures is as follows :—Cast iron consists essentially of an alloy of iron and carbon ; in ordinary cast iron the carbon is present largely as graphite flakes, but about 0·4–0·8% remains combined with the iron and is present in the metal as iron carbide. It is this iron carbide which is unstable and which tends to break down into iron and graphite. This failure may occur at the temperature of superheated steam—i.e., as low as 400° C. The change results in a weaker type of structure and also in a change of volume. On the other hand, if the castings are heated to a temperature of 700° C. or over, the iron carbide remaining in the metal is reabsorbed into the matrix and on cooling separates again, both of which phenomena are accompanied by further volume changes and, generally, by an additional breakdown of the carbide to graphite. These changes are at the root of growth, since the volume change which accompanies them causes internal stress and cracking which generally follows the lines of the graphite flakes already present in the metal.

Iron, at high temperatures, burns or oxidises in the normal atmosphere, in steam or in the furnace gases to which it is exposed. The cracks formed by the volume change, to which reference has been made, open up the metal and allow penetration of these gases into the body of the casting, leading immediately to internal oxidation of the graphite and the metal. The products of this oxidation are themselves of greater volume than the metal from which they are derived, so that on cooling further stresses are set up which result in further opening and weakening of the casting.

The Development of Heat-resisting Cast Iron

Developments in improving the properties of cast iron at high temperature have tended mainly in two directions, either to stabilise the iron carbide in the casting, thus preventing its breakdown in service, or, alternatively, to suppress the structural change which takes place at critical temperatures. Although the initial cause of growth and decay in iron castings at high temperatures is structural change in the metal, the ultimate factor leading to the failure of the casting is oxidation or burning. A further direction, therefore, in which the heat-resistance of iron castings may be improved is by the use of additions which tend to increase the resistance of the body of the metal itself to such attack.

It has been realised for some time past that the silicon always present in cast iron plays a vital part in rendering the carbides increasingly unstable, and it is now recognised that the worst growth occurs in the common, relatively high silicon, types of iron. The first step in developing the heat-resisting cast iron, therefore, has been to reduce the silicon to the minimum permissible having in view the other requirements of the castings.

The introduction of other alloy elements is also known to stabilise the carbides in iron castings, the most valuable element from this point of view being chromium. High manganese or high sulphur, and also additions of molybdenum have a definite effect in adding stability to the iron carbide.

The development of heat-resisting cast irons along the lines indicated, however, tend to develop hard, brittle structures which are in some cases unmachinable and which have little resistance to mechanical or thermal shock.

The use of nickel additions to cast iron has had a profound influence in increasing the general suitability of these irons for service at high temperatures. Small additions of nickel alone have no very definite influence on the heat-resisting properties of cast iron. They are, however, of the greatest importance and value when used in conjunction with a reduction of silicon or an addition of chromium, since nickel has a profound influence in eliminating chill, and thus improving the machinability of the castings, and toughening the metal. In other words, nickel eliminates the disadvantages likely to be met with ,low silicon or with chromium, in heat-resisting castings, and thus enables the full value of these adjustments to be realised. It is for this reason that for heat-resisting castings which require to be machined, or in which a measure of toughness against thermal or mechanical shock is required, a combination of nickel and chromium or nickel with low silicon is both efficient and reliable.

Heat-resistance with Machinability

The question of machinability is of vital importance in many types of engineering castings. At the same time, there are many parts of internal combustion engines and of superheated steam equipment in which machinability must be accompanied by a high degree of heat-resistance and pressure tightness. Examples are found, for instance, in the very complicated castings required for Diesel engine cylinder heads, in manifolds, and also in headers for superheaters for steam equipment. In all these types of castings growth and cracking must be avoided, but, on the other hand, the use of additions of chromium is strictly limited by the difficulty in machining which they introduce and the brittleness which they induce, with consequent danger of cracks by the stresses imposed on the casting in service. These considerations of production requirements with maximum stability in service have led to the choice of such compositions of cast iron as those containing 1·0–1·5% of nickel with 0·5–0·75% of chromium, or sometimes with chromium raised to 1%.

A further point which might be mentioned in this connection is that in complicated castings, in which a nickel-chromium composition is used to give heat-resistance, together with pressure tightness and machinability, it is often beneficial to subject the castings before machining to a heat-treatment by annealing at a temperature of about 600° C. for one hour for each inch of section thickness. Such a treatment relieves internal casting stress, stabilises the structure and improves machinability. Other important applications in engine construction, in which

the properties of nickel-chromium cast irons are desirable include, for example, Diesel cylinder liners, where a measure of heat-resistance is among the numerous properties required, so that the inner surface of the metal may withstand the high temperatures involved.

The nickel-chromium grey cast irons are of special interest for castings subjected to superheated steam, and are proving eminently satisfactory for valve bodies, low-pressure turbine casings, turbine diaphragms, and other parts where stability is essential at elevated temperatures. In these cases the stabilising heat-treatment as described is desirable when it can be applied.

Heat-resistance With Toughness

Many of the castings subjected to heat need no machining. In service, however, they may be subjected to a certain amount of mechanical shock or alternatively to thermal shock, as by the impingement of flames. In these cases again the nickel-chromium combination is being adopted, the chromium conferring heat-resistance whilst the nickel neutralises the brittleness induced by the chromium addition. The usefulness of nickel in this connection extends to castings which may have a high combined carbon content and may therefore be white or mottled in fracture. These structures are, of course, not suitable for castings which have to be machined, but they are permissible for unmachined parts, such as fire-bars and furnace castings in which the only requirements are heat-resistance with a measure of toughness. It may be emphasised that these white or mottled irons produced from materials with low silicon content or with a relatively high chromium content usually have a higher degree of heat-resistance than the grey irons mentioned previously. The main application of these irons is for furnace castings, including clinker dams, dampers, fire doors and stoker parts.

The High Alloy Heat-resisting Cast Irons

One of the most interesting recent developments in alloy cast irons is that of the so-called "Austenitic" cast irons. These contain higher proportions of alloy additions, principally nickel, as a result of which the structural transition range of temperature mentioned earlier in this article is depressed below room temperature, so that under normal conditions the metal consists wholly or austenite, the form of iron normally stable only at high temperatures.

The austenitic cast irons are of special value for heat-resisting purposes not only because the matrix of the metal is resistant to oxidation, but also because the amount of combined carbon normally found in the metal is low, and no structural change takes place on heating. For these reasons such irons as the well-known nickel-copper-chromium iron "Ni-Resist" and the nickel-silicon-chromium iron "Nicrosilal"* have been developed. These irons are stable at relatively high temperatures, and have been found to possess many valuable properties required in heat-resisting castings. For example, a recent research at the National Physical Laboratory† has established the fact that Ni-Resist has a useful degree of creep strength, and at high temperatures the castings will safely sustain relatively high loads.

The austenitic cast irons have been used extensively for heat-resisting castings. They are adopted for such arduous service as burner parts, superheater tube spacers and hangers, soot-blower nozzles and pipes, whilst in Diesel engines they have proved successful for such vital parts as vortex castings, combustion chambers and throats, for flame plates on light alloy pistons and even for valves and seats in certain types of internal combustion engines.

The austenitic cast irons are readily cast and machined to the most complicated shapes and unquestionably have made a valuable contribution to the development of internal combustion engines and boiler equipment.

*Developed by the B.C.I.R.A. and covered by Brit. Pat. 378508.

†Tapsell, Becker and Conway: "The Behaviour of Five Cast Irons in Relation to Creep and Growth at Elevated Temperatures." *Journal of the Iron and Steel Institute*, 1936, No. 1, p. 303.

Conclusion

It is difficult to give specific temperature ranges in which the heat-resisting alloy cast irons may be applied, since so much depends on the loading to which the castings are subjected and on the atmosphere to which they are exposed. There is no doubt, however, that both the low alloy and the austenitic types of cast iron have filled a long-felt want in providing castings with improved heat-resistance and with properties which lie mid way between the older types of cast iron and the more specialised heat-resisting alloys, such as the heat-resisting steels and the high-nickel-chromium alloys available to-day.

Additional Ore-Testing Facilities at Ottawa

ARISING from the steady expansion in metal mining operations throughout the Dominion, the Canadian Department of Mines and Resources has made an important extension to its ore-dressing and metallurgical laboratories, where investigations on the treatment of gold ores and other metals are carried out. The new building, which is now ready for use, is 60 ft. by 100 ft., with a basement and three storeys. It adjoins the existing buildings, and is located close to the railway siding so that ore shipments can be conveniently transferred.

One quarter of the new space is allotted to a crushing and sampling plant with a capacity of 4 tons per hour, to provide a long-desired service to mine operators who require an accurate idea of the value of representative shipments from their ore bodies. In the remaining space are apparatus for grinding, classification, gravity, and flotation concentration, and magnetic concentration, along with the machinery necessary for the cyanidation of ores, the equipment being so placed that the combination is adaptable with a minimum expenditure of time and effort.

A complete cyanidation unit is provided for the test work on the extraction of gold from its ores. This "pilot plant," consisting of a ball mill, classifier, thickeners, agitator tanks, filters, and a precipitation unit, is capable of milling up to 2 tons in 24 hours.

Some Aspects of the Non-Ferrous Metals Trade

(*Continued from page* 226)

an increase of one to 1¼ in. in steel. Similar percentages govern reductions in sectional areas. A curious contrast in the working of steel is the rule that as much work as possible is accomplished in the hot state, whereas, in non-ferrous metals, especially copper, it is done in the cold state. It is not unusual to reduce the sectional area of copper hollows by as much as 40 to 50 per cent.

Push-and-Pull Benches

Much discussion has arisen regarding the usefulness of the hydraulic push bench in comparison with a heavy slow-speed draw bench and, to the author's knowledge, one prominent firm dismantled a 200-ton hydraulic push bench on the grounds that it produced eccentric walls in tubes, overlooking the fact that they had so arranged the bench that both the drawing-bar and drawing-die were securely fixed, which tools in comparison with both methods—push and pull—should have been floating. Another advantage of the push bench in comparison with the pull bench, is that it is not necessary to pull back and reverse the tube and bar for extraction of the latter.

It is appreciated that, on a push bench, finishing processes are not dealt with, but, as an offset to this, with a far greater sectional reduction it is possible to finish tubes in two passes, the final one over a plug on the chain bench, as against four or more where only chain benches are available. The comparison, especially in the case of large diameters, is favourable to the hydraulic push process, and, in some cases, similar results are obtained with cast hollow shells of various alloys treated on high speed, short-stroked push benches of the hydraulic type.

Business Notes and News

Iron and Steel Expansion

Although the attitude of consumers of iron and steel has been very cautious in recent weeks, there are definite indications of improvement in iron and steel markets, and in recent weeks an expansion of business in practically all departments has been experienced. The recession in the steel trade certainly appears to have been definitely checked, and more steel furnaces are now working. There is a marked broadening of commercial demand, and a number of firms have received a good deal of work in connection with rearmament, and structural steel is fairly active. Stocks of sheets have been greatly reduced to meet air raid precaution requirements, and these are being slowly made good. It will be seen, therefore, that the requirements of the accelerated armaments programme have been a partial cause of improvement, there has also been a revival in demand for ordinary commercial purposes, but it is noteworthy that the increased activity has been almost entirely confined to the home market.

In the pig-iron section there has been increased demand. Most consumers of foundry iron have exhausted their stocks and are turning to makers for deliveries which are being made from dwindling accumulations at the works. Makers of hæmatite are delivering larger tonnages against old contracts, and progress is being made in the liquidation of stocks which remain. The position has eased considerably, and there is increased call for specifications. Considerable tonnages are also reaching the steelworks. A sharp expansion in steel output last month brought the total to within a few thousand tons of the record production in November, 1937. The total for the month was 1,170,900 tons. Pig iron production rose to 603,000 tons, the best since May last.

Strongford Power Station Scheme Approved

The North-West Midland Electricity Authority has approved a scheme for the erection of a big power station for the grid, to serve the North-West Midlands, at a cost of £2,500,000. The station, which will take four years to complete, is to be erected at Strongford, which is just inside the Stoke boundary.

The scheme is to be financed by the North-West Midlands Joint Electricity Authority on behalf of the Central Electricity Board. The station will be erected in sections, and the first part will cost about £1,250,000.

Plastic Cycle Frames

A cycling publication comments that "experiments are being carried out in Germany, as well as in this country, on a new plastic material made from a mixture of paper and cardboard combined with resin, and compressed. Almost all the parts of a motor-car, except the engine, gearbox, and transmission, can be made from this new material, and I am wondering whether anyone will try their hands at making cycle frames with this stuff."

Admirable as are the qualities of many of the present plastic materials, we should have grave doubts as to the possibility of making those parts of a car, which are not excepted by the writer of the preceding paragraph, of a plastic made from paper, cardboard and resin. We should not care to ride over even the smoothest surface on a car built up on a plastic frame, with brake drums and shoes, steering gear, track rod and front axle of that material, and sprung with springs of plastic material. It may be useful for the bodywork and interior fittings, but for vital and often highly-stressed parts, there is no known substitute for metal. Perhaps it is that element of novelty that so often leads to enthusiasm and the envisaging of possibilities that more mature judgment would show to be impracticable.

No. 278,851 Improvement in the Purification of Zinc Solutions Preparatory to Recovery of Zinc by Electrolysis.

The Owners of the above patent are desirous of arranging by license or otherwise on reasonable terms for the manufacture and commercial development of the invention. For particulars address in the first instance to Herbert Haddan and Co., 31 and 32, Bedford Street, Strand, London W.C.2.

Vickers Armstrong, Ltd.

The above company is largely engaged on armament work, and at the beginning of this year had under construction, at Barrow, two aircraft carriers and six submarines for the Royal Navy. Since then an order has been received for a cruiser for the Royal Navy. In addition to these vessels, two destroyers are in course of construction for the Brazilian Navy, and orders for two destroyers and four submarines have been placed by the Turkish Government. The extension of the fitting-out wharf at Barrow has been completed. This is equipped to deal with three large liners or aircraft carriers simultaneously, and has greatly improved the facilities available for this work.

The main products of the Elswick works also have been those required by the Service departments, and production has been very satisfactory. Work in hand at the Naval yard, Newcastle, includes a Tribal class destroyer, a battleship, an aircraft carrier, and a cruiser. Since the beginning of this year orders received comprise a further battleship, a cruiser, and two destroyers. Great progress has been made in the re-equipment of the Scotswood works, and modifications are now in progress to enable the manufacture of aeroplane components to be undertaken. The works at Openshaw are equipped to deal with certain types of armament which are normally produced at Crayford, and production is proceeding at a rapid rate. The works at Crayford and Dartford and the Thames Ammunition Works also are chiefly engaged in connection with the defence programme. Manufacturing facilities at Weybridge and Southampton have been increased, and both works are contributing to the larger output of aircraft called for by the Air Ministry.

American Co-ordinating Committee on Corrosion

A number of technical societies and other organisations engaged in the study of corrosion have joined in forming the American Co-ordinating Committee on Corrosion, which is to serve as a clearing house and co-ordinating agency for information on experience and work in progress in the field of corrosion and corrosion prevention. The formation of this Committee will, it is expected, meet a need which both individuals and organisations have felt for such a clearing house for information on corrosion work. As its first step, the Committee is compiling a list of the names and addresses of those working in the field of corrosion in America, together with information as to their special interests and their current programmes of corrosion studies. To this end the Committee is using the facilities of the various co-operating societies, supplemented by the extensive knowledge of its members on corrosion studies in progress throughout industry. Information is being sought respecting the names of individuals and organisations engaged in corrosion studies, the nature of such studies, and a record of experience and publications. The compilation of such information will serve many useful purposes both to individual workers in the field and to the various technical and industrial organisations that plan and carry out corrosion studies of many different kinds. It is not the purpose of the Co-ordinating Committee to abstract the literature on corrosion.

The next meeting of the Committee will be held in June at Atlantic City, N.J., during the A.S.T.M. annual meeting, at which the information thus far compiled will be reviewed, permanent organisation effected, and the work of the Committee further considered. Pending permanent organisation, C. L. Warwick, Secretary-Treasurer of the American Society for Testing Materials, is serving as temporary chairman of the Committee.

Personal

Mr. D. Cannon Brookes, M.A., manager of Aluminium Information Bureau, Bush House, London, which was inaugurated by Northern Aluminium Co., Ltd., in 1937, has left to take up an executive position with Aluminium Union, Ltd. Mr. E. D. Iliff, B.Sc., who has been technical sales advisor to the Birmingham works of Aluminium Union, Ltd., has taken over the managerial duties of the Information Bureau.

Mr. J. E. Hurst is to have conferred upon him the honorary degree of Doctor of Metallurgy by Sheffield University. The honour will be conferred at a Degree Congregation on July 1.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£95	0	0

ANTIMONY.

English	£71	0	0
Chinese	49	0	0
Crude	36	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11½
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9½
Wire	,,	0	0	8½
*Extruded Brass Bars	,,	0	0	4¼

COPPER.

Standard Cash	£42	2	0
Electrolytic	42	10	0
Best Selected	47	5	0
Tough	48	0	0
Sheets	80	0	0
Wire Bars	48	10	0
Ingot Bars	48	10	0
Solid Drawn Tubes lb.	0	1	0¾
Brazed Tubes ,,	0	1	0¾

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten ° nominal	,,	0	4	8
Ferro Molybdenum ° ,,		0	4	10
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL 6–8 Carbon, scale 7/6 per unit	,,	23	15	0
NOMINAL 8–10% Carbon, scale 7/6 per unit	,,	23	15	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	7

FUELS.

Foundry Coke—			
S. Wales	£1 18	0/£2	1 6
Scotland	£1 10	0/£1	15 0
Durham	—	1	14 6
Furnace Coke—			
Scotland	£1 5	0/£1	7 6
S. Wales	—	1	7 6
Durham	—	1	4 2

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£69	0	0
*Commercial Ingots	49	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards lb.	0	0	11
*Cored Bars ,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£12	5	0
N.E. Coast—			
Rivets	—		
Best Bars	12	15	0
Crown Bars	12	5	0
Lancashire—			
Crown Bars	12	5	0
Hoops	13	12	6
Midlands—			
Crown Bars	12	5	0
Marked Bars	13	5	0
Unmarked Bars	—		
Nut and Bolt Bars	11	0	0
Gas Strip	13	12	6
S. Yorks.—			
Best Bars	12	5	0
Hoops	13	12	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11½
†Sheet to 10 W.G.	,,	0	1	0
†Wire	,,	0	1	1½
†Rods	,,	0	1	1½
†Tubes	,,	0	1	6¾
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	13	0
Foundry No. 1	6	0	6
,, No. 3	5	18	0
N.E. Coast—			
Hæmatite No. 1	6	0	0
Foundry No. 1	5	2	0
,, No. 3	4	19	0
,, No. 4	4	18	0
Silicon Iron	—		
Forge	4	18	0
Midlands—			
N. Staffs. Forge No. 4	4	18	0
,, Foundry No. 3	5	1	0
Northants—			
Foundry No. 1	5	1	6
Forge No. 4	4	17	6
Foundry No. 3	4	18	6
Derbyshire Forge	4	18	0
,, Foundry No. 1	5	4	0
,, Foundry No. 3	5	1	0
West Coast Hæmatite	6	12	0
East ,, ,,	6	11	0

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.160
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton	£19 12 2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.230-250
Per English ton	£12 1 2/£13 2 2
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton f.o.b. Gothenburg.	£18 17 6

SCRAP METAL.

Copper, Clean	£35	0	0
,, Brazierv	33	0	0
,, Wire	—		
Brass	21	10	0
Gun Metal	35	0	0
Zinc	8	10	0
Aluminium Cuttings	59	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	2	0
Scotland	2	19	0
Cleveland	3	0	0
Cast Iron—			
Midlands	2	15	0
S. Wales	3	2	0
Cleveland	3	12	6
Steel Turnings—			
Cleveland	—		
Midlands	2	0	0
Cast Iron Borings—			
Cleveland	—		
Scotland	1	14	0

SPELTER.

G.O.B. Official	—		
Hard	£9	5	0
English	14	10	0
India	13	5	0
Re-melted	10	0	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£10	10	6
North-East Coast	10	10	6
Midlands	10	10	6
Boiler Plates (Land) Scotland	11	8	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	11	8	0
,, ,, (Marine) ,,	—		
Angles, Scotland	10	8	0
,, North-East Coast	10	8	0
,, Midlands	10	8	0
Joists	10	8	0
Heavy Rails	9	10	0
Fishplates	13	10	0
Light Rails	9	13	6
Sheffield—			
Siemens Acid Billets	10	10	0
Hard Basic £8 10 0 to	10	0	0
Medium Basic, £7 12 6 to	7	17	6
Soft Basic	7	7	6
Hoops	11	15	0
Manchester			
Hoops	12	7	0
Scotland, Sheets 24 B.G.	14	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras:				
Round and Squares, ¼ in. to ½ in.	,,	0	0	3
Under ½ in. to 1/16 in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ¾ in.	,,	0	0	3
,, ,, ½ in. × ½ in.	,,	0	1	0

TIN.

Standard Cash	£215	10	0
English	215	5	0
Australian	—		
Eastern	219	15	0
Tin Plates I.C. 20 × 14 box	1	0	3

ZINC.

English Sheets	£28	5	0
Rods	28	5	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£14	1	0
English	16	0	0

* McKechnie Brothers, Ltd., April 11. † C. Clifford & Sons, Ltd., April 11. ‡ Murex Limited, April 11.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, April 11. ¶ The prices fluctuate with the price of Tungsten.

SAVE WEIGHT BY USING "ELEKTRON" THE PIONEER MAGNESIUM ALLOYS

BY USING

ELEKTRON

REGISTERED TRADE MARK

the pioneer

MAGNESIUM ALLOYS

40% LIGHTER THAN ALUMINIUM—COMPARABLE IN STRENGTH

• ***Sole Producers and Proprietors of the Trade Mark "Elektron"***: MAGNESIUM ELEKTRON LIMITED, Works, near Manchester • ***Licensed Manufacturers:*** *Castings:* STERLING METALS LIMITED, Northey Road, Foleshill, Coventry • THE BIRMINGHAM ALUMINIUM CASTING (1903) COMPANY LIMITED, Birmid Works, Smethwick, Birmingham • J. STONE & COMPANY LIMITED, Deptford, London, S.E.14 • *Sheet, Extrusions, Forgings & Tubes:* JAMES BOOTH & CO. (1915) LIMITED, Argyle Street Works, Nechells, Birmingham, 7 • *Sheet, Extrusions, Etc.:* BIRMETALS LIMITED, Woodgate, Quinton, Birmingham • ***Suppliers of Magnesium and "Elektron" Metal for the British Empire:*** F. A. HUGHES & CO. LIMITED, Abbey House, Baker St., London, N.W.1

The A B M T M group of machine tool makers covers the whole field of machine-tool building, giving the engineer at home and abroad a unique manufacturing and sales service.

Apart from the main specialities of the Associated firms, customers have the advantages of the pooled research, the accumulated experience and the entire technical resources of the whole group.

The abundant advantages thus provided by group co-operation will be obvious. The after-sales service is of a kind beyond the scope of the single manufacturer.

For further particulars write to:

17, GROSVENOR GARDENS

LONDON——————————S.W.1

SPECIALISTS
in High Strength
BRASSES & BRONZES
Parsons' Manganese Bronze.—Ultimate Tensile Strength 33 to 36 tons per square inch meets the requirements of Specification B.S.I. 250A and B, and A.I.D. 3.B.I.
Immadium High Strength Bronzes—for high strength, toughness and resistance to chemical corrosion. Ultimate Tensile Strength up to 50 tons per square inch. (Immadium VI.)
Crotorite Aluminium Bronzes.—Zinc-free Alloys with exceptional resistance to both Chemical and Galvanic corrosion and retaining good Physical Properties at elevated temperatures, including Alloys to meet the requirements of the following Aircraft Specifications: DTD135, DTD160, DTD164, DTD174 and DTD197.
Damaxine Phosphor Bronzes—available in eight grades to meet all Bearing requirements and with free machining properties where necessary. Damaxine withstands the heaviest loads and highest speeds encountered in service.
THE MANGANESE BRONZE & BRASS CO. LTD
HANDFORD WORKS. IPSWICH. Telephone:- IPSWICH 2127
techdesign

FILE THIS IN YOUR CABINET

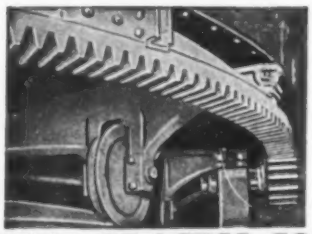
You will then be able to refer to contents of previous issues easily.

METALLURGIA. Contents. For APRIL, 1939.

	Page
The Canadian Aluminium Industry *The Canadian aluminium industry goes back to 1899, when the construction of the Shawinigan Falls smelter was begun. The industry is briefly reviewed.*	205–207
Development in Empire Tungsten Production	208
British Shipping and Shipbuilding	209
Iron and Steel Institute Annual Meeting	210
Trade Mission to the United States	210
The Stelliting of Exhaust Valves and Valve Seats. By S. A. J. Sage *Modern materials have increased the utility of poppet-valve engines. One of these materials is Stellite, and in this article its application to valves and seats is discussed.*	211–214
British Chemical Standards	214
Industrial Management and Production Control. By F. L. Meyenberg *The discussion of the time study man and his task is continued.*	215–217
The Mechanism of the Reaction between Hydrogen and Carbon in Iron	217
The Influence of Some Special Additions on Certain Properties of Cast Iron	218
Metal-Sprayed Bearings for High-Speed Operations	219–220
Protection of Steel against Corrosion	220
Strength of Marine Engine Shafting *The Strength of marine engine shafting is considered, based on experience and the result of thorough investigation into the causes of failure.*	221–222
Contact Corrosion of Stainless Steel By John Arnott, F.I.C. *Local attack on some types of stainless steel in contact with apparently innocuous non-metallic substances, under wet conditions, is discussed.*	223–224
Some Aspects of the Non-Ferrous Metals Trade. By Gilbert Evans *The increasing demand for non-ferrous tubes is reflected in the many installations of plant recently put into operation or in course of construction. Some new installations are discussed.*	225–226
Per Capita Output and Labour Planning	227–228
Surface Rolling of Aeroplane Propellers	228
Soviet Ferrous Metallurgy under the Third Five-Year Plan. By a Special Correspondent *The progress achieved from previous construction schemes in the U.S.S.R. is referred to and an outline given of a new five-year scheme.*	229–230
Recent Developments in Materials, Tools and Equipment *Rotary Exhausters and Compressors. A Lubricant for Rubber.*	231–232
Reviews of Current Literature	233–234
Some Applications for Heat-Resisting Nickel Cast Iron *Under modern conditions the usefulness of ordinary cast iron for heat-resisting purposes is strictly limited. Some alloy cast irons for this purpose are discussed.*	235–236

"SHORTER"

Local Surface Hardening with Precision (patented)



All wearing parts can be Shorterised

SHORTER PROCESS CO. Ltd.
Savile Street East, Sheffield 4.

There is a **"HARDENITE"** case-hardening compound suitable for any case-hardening operation, whether it be a question of uniformity, quick penetration, repetition, absence of freckle, or rapid case-hardening in the open hearth. "Hardenite" compounds are made solely by

The
AMALGAMS Co., Ltd.
184, Attercliffe Rd., SHEFFIELD.

AMSLER TESTING MACHINES

Unequalled for rapid and accurate testing, for ease of operation and for low maintenance costs

T. C. HOWDEN & Co.,
5 & 7, Fleet Street, Birmingham, 3

JUST PUBLISHED.

METAL SPRAYING.

By E. C. ROLLASON, M.Sc., T. HENRY TURNER, M.Sc., and N. F. BUDGEN, M.Sc., Ph.D.

Contents: Early Attempts at Metal Spraying—The Development of the Modern Metal Spraying Pistols—Modern Metal Spraying Pistols—Sand Blasting and Efficiency of Spraying—Nature of Sprayed Metal—Comparison of the Metal-Spray Process with Other Methods of Metallisation—Applications of the Metal-Spray Process—Appendix—Index of Names—Index of Subjects.

SECOND EDITION. Medium 8vo. 235 pages. 197 illustrations + 39 Tables.
Price 15s. net. Postage 6d. Abroad 1s.
"A thoroughly practical book."—*The Metal Industry.*

CHARLES GRIFFIN & CO., LTD.
42, DRURY LANE, LONDON, W.C. 2.

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Alloys
J. H. Clifton, London.
Electric Furnace Products Co., Ltd., Norway.

Aluminium and its Alloys
Aluminium Union, Ltd., The Adelphi, Strand, London, W.C. 2.
Earle, Bourne & Co., Ltd., Heath Street South, Birmingham.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C. 2.
Priestman, T. J., Ltd., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.

Anti-Friction Metals
Earle Bourne & Co., Ltd., Birmingham.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Billington & Newton Ltd., Longport.
Clifford, Chas. and Son, Ltd., Birmingham.
Earle, Bourne & Co., Ltd. Heath Street South, Birmingham.
Emery Bros., Ltd., Aston, Birmingham.
I.C.I. Metals Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co., Ltd., Handford Works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C. 1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove St., Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Co_2 Recorders
Honeywell Brown, Ltd., 70, St. Thomas St., London.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Rd., Middlesbrough.

Crucibles
Morgan Crucible Co. Ltd., Battersea Church Rd., London, S.W. 11.

Diecastings
Diecastings, Ltd., Moseley Rd., Birmingham 12.

Electrodes
British Acheson Electrodes, Ltd., Sheffield.

Extruded Rods and Sections
Earle Bourne & Co., Ltd., Birmingham.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C. 6, Imperial Chemical House, London, S.W. 1.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Rd., Manchester.
Thos. Wilkinson & Co., Ltd., Middlesbrough.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Elektrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G. W. B. Electric Furnaces, Ltd., Belgrove House, Belgrove St., London, W.C. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.
Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Rd., London, N. 7.

Furnaces (Fuel)
Brayshaw Furnaces Ltd., Manchester.
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., Hillington, Glasgow.
Cassel Cyanide Co., Ltd., Room 170F2, Imperial Chemical House, London, S.W. 1.
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.

Furnaces (Fuel)—*continued*
King, Taudevin & Gregson, Ltd., Sheffield.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.
Wellman Smith Owen Engineering Corporation Ltd., Victoria Station House, London.

Fused Blocks
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester.
Shorter Process Co., Ltd., Savile St. East, Sheffield.

Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.
I.C.I. Cassel Cyanide.

Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Ironfounders.
Joshua Bigwood & Son, Ltd., Wolverhampton.

Machinery
Joshua Bigwood & Son, Ltd., Wolverhampton.

Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.

Magnesium Alloys
F. A. Hughes Ltd., London.
Magnesium Castings, Ltd., Slough.
Sterling Metals, Ltd., Coventry.

Magnetic Separators, Clutches, Chucks, and Lifting Magnets
Electromagnets, Ltd., 48, High St., Erdington, Birmingham.

Metal Spraying
Metallisation Ltd., Dudley.

Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Non-Ferrous Metals
Birmetals, Ltd.
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.

Oil Engines
Mirrlees Bickerton & Day, Ltd., Stockport.

Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bradley & Foster, Ltd., Darlaston.

Presses
Eumuco Ltd., Beverley Works, Willow Ave., Barnes, London, S.W. 13.
Schloemann, A.-G., Düsseldorf, Germany.

Protection of Metal Parts for Use at High Temperatures
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.

Pulverised Fuel Manufacturers
Standard Pulverised Fuel Co., Ltd., 4-5, Norfolk St,, Strand, London, W.C,2.

Pyrometers
Cambridge Instrument Co., Ltd., London.
Electroflo Meters Ltd., Abbey Rd., Park Royal, London, N.W. 1.
Ether Ltd., Tyburn Rd., Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas St., London.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.

Recording Instruments
Cambridge Instrument Co., Ltd., London.
Dine Engineering Co., 60, Mount St., Nechells, Birmingham.
Electroflo-Meters Co., Ltd., Abbey Rd., Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Rd., Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.

Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
J. and J. Dyson, Ltd., Stannington, Sheffield.
Kingscliffe Insulating Products, Ltd., Sheffield.
Thos. Marshall and Co., Loxley, near Sheffield.
Morgan Crucible Co., Ltd., Battersea Church Rd., London, S.W. 11.
John G. Stein & Co., Bonnybridge, Scotland.

Regulators
Honeywell Brown Ltd., 70, St. Thomas St., London.

Roll Grinding Machines
Craven Bros. Ltd., Reddish, Stockport.

Roll Manufacturers
Tennent Ltd., Whifflet Foundry, Coatbridge, Scotland.

Rolling Mills
Demag, A.-G., Germany.
Ehrhardt and Sehmer, Saarbrücken.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain: J. Rolland and Co., 2, Victoria St., London, S.W. 1.
Lamberton and Co., Coatbridge.
Maschinenfabric Froriep, Rheydt, Germany.
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.-G., Germany.
Karl., Fr. Ungerer., Germany.

Silver Solder
Chas. Harrold & Co. Ltd., 283, St. Paul's Square, Birmingham.

Steels
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield.
L. Cameron & Sons, Ltd., Sheffield.
Daniel Doncaster & Sons, Ltd., Sheffield.
Darwins, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
Thos. Firth & John Brown, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Mills, Exors of James Ltd., Stockport.
Refined Stainless Steel Co., Ltd., Rotherham.
Sanderson Bros. and Newbould, Ltd., Sheffield.
United Steel Companies, Ltd., Sheffield.

Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.

Steel Tubes and Sections
Reynolds Tube Co., Tyseley, Birmingham.

Steelworks Plant
Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.

Temperature Controllers
Cambridge Instrument Co., Ltd., London.
Electroflo-Meters Co. Ltd., Abbey Rd., Park Royal, London.
Ether, Ltd., Tyburn Rd., Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas St., London, S.E. 1.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
George Kent, Ltd., Luton.

Testing Machines
Howden, T. C., and Co., 517, Fleet Street, Birmingham.

Thermostatic Controls
Honeywell Brown Ltd., 70, St. Thomas St., London.

Tube Drawing Plant
Sundwiger Eisenhütte, Sundwig, Germany.

Turbines
Richardson, Westgarth Ltd., West Hartlepool.

Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

X-Ray Apparatus
Victor X-Ray Corporation Ltd., London and Chicago.

Subscription Form

METALLURGIA

To

THE KENNEDY PRESS, LTD.,
21, ALBION STREET,
GAYTHORN, MANCHESTER 1.

Please send us **"METALLURGIA"** *monthly until countermanded at our discretion.*

Invoice @ 12/- half-yearly

Name.....

Address.....

.....

Index to Advertisers.

	PAGE
Aluminium Union, Ltd.	32
Amalgams Company, Ltd.	38
Armstrong Whitworth, Ltd.	—
Associated British Machine Tool Makers, Ltd.	36
Barrow Hæmatite Steel Co., Ltd.	Inside Back Cover
Bigwood, Joshua, & Sons, Ltd.	24
Billington & Newton, Ltd.	—
Birmetals, Ltd.	—
Birmingham Electric Furnaces, Ltd.	17
Bradley & Foster, Ltd.	—
Brayshaw Furnaces Ltd.	24
British Acheson Electrodes, Ltd.	15
British Commercial Gas	—
British Furnaces	—
Burdon Furnaces	—
Calorizing Corporation, Ltd.	—
Cambridge Instrument Co.	—
Cameron, L., & Sons, Ltd., Sheffield	—
Carborundum Co., Ltd.	3
Clifford, Chas., & Son, Ltd.	15
Darwins Ltd.	—
Demag, A.-G.	18
Demag Elektrostahl	4
Diecastings Ltd.	—
Doncaster, Daniel, Ltd.	4
Dowson & Mason, Ltd.	20
Dunford, Elliott, Ltd., Sheffield	—
Electric Furnace Co., Ltd.	29
Electromagnets, Ltd.	—
Electroflo Meters Co., Ltd.	9
Electric Furnace Products Co., Ltd., Norway	—
Emery Bros., Ltd.	—
English Steel Corporation, Ltd.	—
Ether, Ltd.	20
Earle Bourne & Co., Ltd.	—
Eumuco, Ltd.	—
Firth-Brown, Ltd.	—
Foundry Services Ltd., Birmingham	—
Fox, Samuel & Co., Ltd.	8
Gibbon Bros., Ltd.	10, 11, 30
General Electrical Co., Ltd.	—
G. W. B. Electric Furnaces, Ltd.	—
Griffin, C. & Co., Ltd.	38
Harrold, Charles, & Co., Ltd.	—
Herbert, Alfred, Ltd.	—
High Duty Alloys, Ltd.	5
Holroyd, John, Ltd.	—
Honeywell Brown, Ltd.	—
Howden, T. C., & Co.	38
Hughes, F. A., Ltd., London	35
Imperial Chemical Industries, Ltd.	22, 31
Incandescent Heat Co., Ltd.	19
Industrial Art Services, Ltd.	22
Integra Co., Ltd.	27
Jackman, J. W., & Co., Ltd.	—
Kent, George, Ltd.	Front Cover
King, Taudevin & Gregson, Ltd.	26
Krupp Grusonwerk A.-G.	14
Magnesium Castings, Ltd.	13
Manganese Brass & Bronze Co.	37
Marshall and Co.	—
Maschinenfabrik Froriep	—
McKechnie Brothers, Ltd.	Inside Front Cover
Metallisation Ltd.	—
Metalectric Furnaces, Ltd.	—
Metropolitan-Vickers, Ltd.	28
Mills, W., Ltd.	16
Mill, Exors. of Jas.	—
Mirrlees, Bickerton & Day, Ltd.	—
Mond Nickel Co., Ltd.	—
National Savings Movement	—
Northern Aluminium Co., Ltd.	21
Perry Barr Metals	—
Priest Furnaces, Ltd.	14
Priestman, T. J., Ltd.	—
Refined Stainless Steel Co., Ltd.	—
Reynolds Tube Co., Ltd.	15
Rheinische Walzmaschinen	—
Robertson, W. H. A., & Co., Ltd.	12
Rudge Littley, Ltd.	—
Sanderson Bros., & Newbould, Ltd.	34
Schmitz, A.-G.	16
Schloemann, A.-G.	—
Shorter Process Co., Ltd.	38
Siemens Schuckert	23
Standard Pulverised Fuel	7
Stein, J. G., & Co., Bonnybridge, Scotland	34
Steel, Peech & Tozer, Ltd.	—
Sterling Metals, Ltd.	25
Thermal Syndicate, Ltd.	Inside Front Cover
United Steel Co., Ltd., The	8
Ungerer, Karl Fr.	6
Victor X-Ray Corporation	—
Wallwork, Henry, & Co., Ltd.	Outside Back Cover
Wellman, Smith, Owen, Ltd.	—
Wild-Barfield, Ltd.	—
Wilkinson, Thos.	20
Wilson & Hudson, Ltd.	40

The excellence of the printing of this journal is partly due to the use of perfect blocks—the publishers use

WILSON & HUDSON

LIMITED

FOR THE MAJORITY OF THE HALF-TONE AND LINE BLOCKS USED IN THIS ISSUE.

EVERY KIND OF CREATIVE ART, RETOUCHING AND PHOTOGRAPHY

●

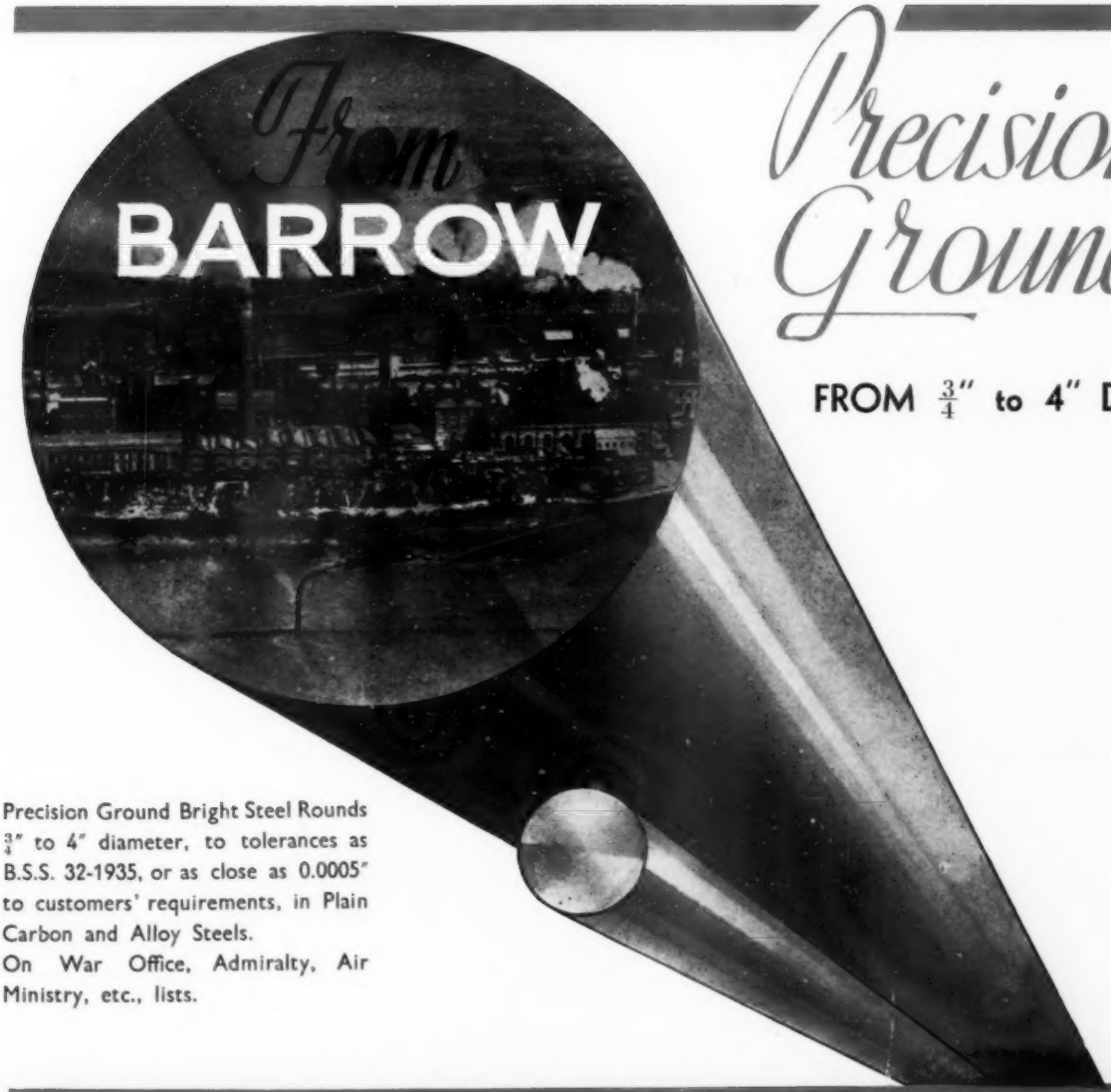
36, YOUNG STREET, QUAY STREET, MANCHESTER *'Phone:* BLA. 4291/2

BRIGHT STEEL ROUNDS

From BARROW

Precision Ground

FROM $\frac{3}{4}$" to 4" DIAM.



Precision Ground Bright Steel Rounds $\frac{3}{4}$" to 4" diameter, to tolerances as B.S.S. 32-1935, or as close as 0.0005" to customers' requirements, in Plain Carbon and Alloy Steels.
On War Office, Admiralty, Air Ministry, etc., lists.

BARROW HÆMATITE STEEL CO. LTD.

BARROW-IN-FURNESS, ENGLAND

Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers (1937), Limited, Hotspur Press, Manchester; and London.

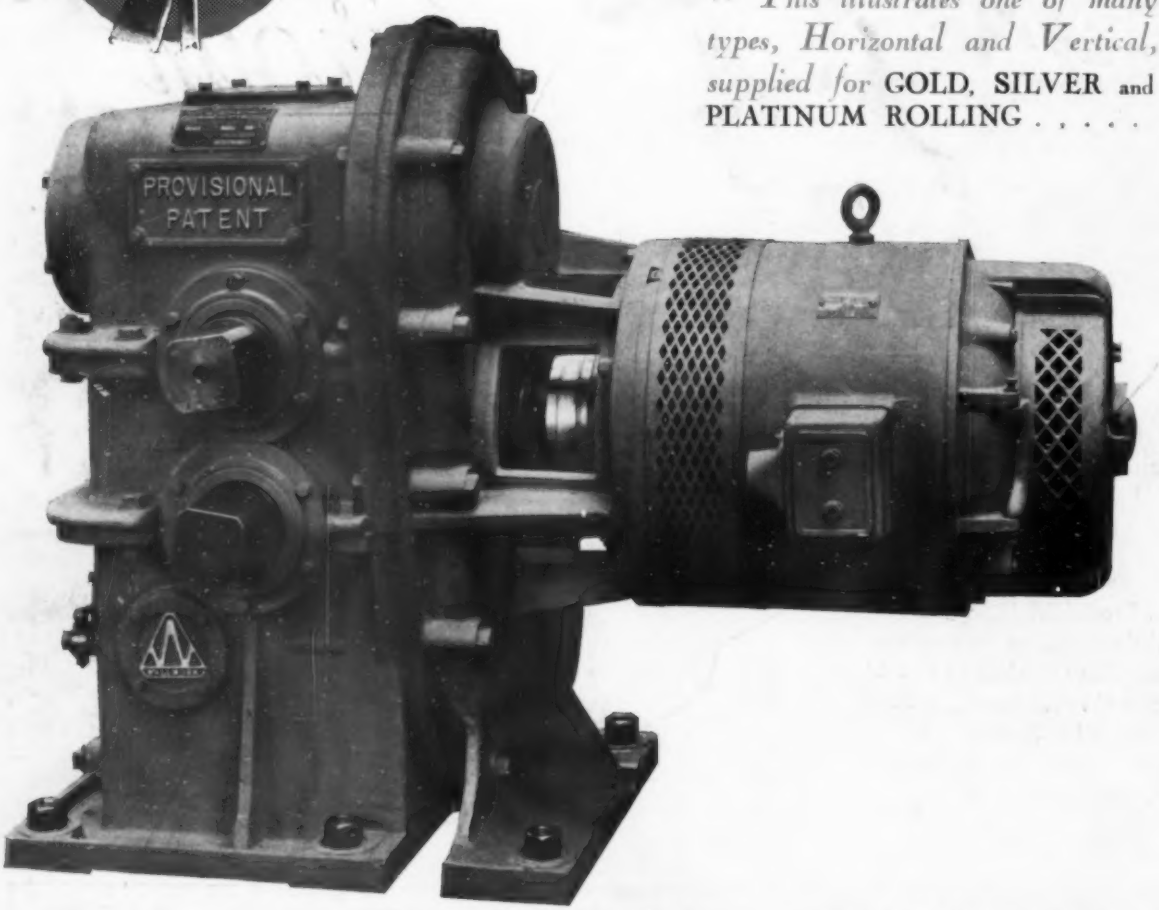
Here is a recently installed

DOUBLE GEARED BULLION ROLLING MILL *for continuous operation*

SPEED REDUCTION 1420 r.p.m. to 28 r.p.m.

Totally enclosed, double wormgear and helical drive.
All shafts arranged on ball and roller journals with means for thrust loads.
Special lubrication is automatic to each gear and shaft bearing.
Whole unit compact, self-contained, oil and dust tight, robust and reliable under arduous conditions of service.

★ *This illustrates one of many types, Horizontal and Vertical, supplied for* GOLD, SILVER and PLATINUM ROLLING . . . . .



WALLWORK GEARS LTD. MANCHESTER

Telegrams : "Foundry, Manchester." *Telephone : BLAckfriars 1801 (3 lines).*